

Experimental Study of Cam Follower Based Power Generation

Prof. R.N. Deshmukh¹, Mr. Ashish Kshirsagar², Mr. Amer Londhe³, Mr. Digambar Mandale⁴

Research Guide, Department of Mechanical Engineering, Sahakar Maharshi Shankarrao Mohite-Patil Institute of Technology and Research Shankarnagar, Akluj¹

Research Student, Department of Mechanical Engineering, Sahakar Maharshi Shankarrao Mohite-Patil Institute of Technology and Research Shankarnagar, Akluj^{2,3,4}

Abstract: The rapid depletion of conventional fossil fuels and the escalating global demand for clean energy have encouraged researchers to investigate small-scale, distributed electromechanical power generation systems. This project presents the design, fabrication, and experimental evaluation of a cam-follower-based power generation prototype that converts controlled reciprocating mechanical motion into usable electrical energy.

The system employs a 12 V DC geared motor operating at 45 RPM as the prime mover. The motor drives a profiled 90 mm cam, which actuates a spring-loaded follower shaft (12 mm diameter, 150 mm spring). A rack machined onto the follower shaft meshes with a pinion mounted on the shaft of a DC permanent-magnet generator, thereby converting the linear reciprocating motion into rotary generator input. The electrical output is rectified, stored in two series-connected 6 V DC batteries (12 V bus), and used to illuminate a 12 V DC LED module. The complete mechanism is mounted on a rigid frame fabricated from 1-inch mild-steel square pipes, with metal bushes providing precision linear guidance for the follower shaft.

Design calculations validate the cam kinematics, spring selection, rack-pinion gear ratios, frame structural integrity, and shaft stress. Experimental measurements of open-circuit voltage, loaded output voltage, and output current yield an average overall system efficiency of approximately 14%, consistent with expectations for a multi-stage electromechanical prototype. The project demonstrates a feasible, low-cost approach to mechanical energy harvesting and serves as a valuable educational platform for studying electromechanical conversion principles.

Keywords: Cam-Follower Mechanism, Energy Harvesting, Spring Design, Mechanical Power Generation.

1. INTRODUCTION

Cam-follower mechanisms are among the oldest and most reliable kinematic devices in mechanical engineering. They are employed extensively in internal combustion engine valve trains, textile machinery, printing presses, vending machines, and industrial automation equipment. Their primary function is to convert continuous rotary motion into precisely controlled reciprocating or oscillating motion with predetermined displacement, velocity, and acceleration profiles. This deterministic and repeatable character makes the cam-follower an ideal candidate for driving a generator in a controlled, cyclic manner.

This project investigates the design, fabrication, and experimental performance of a compact cam-follower-based power generation prototype. A 12 V DC geared motor running at 45 RPM drives a 90 mm profiled cam. The cam actuates a spring-loaded follower shaft (12 mm diameter) whose reciprocating motion is transmitted through a rack-and-pinion assembly to a DC permanent-magnet generator. The electrical output is rectified, stored in two 6 V sealed lead-acid batteries connected in series, and used to illuminate a 12 V DC LED module. The entire mechanism is assembled on a welded frame constructed from 1-inch mild-steel square hollow sections, with metal bushes providing precise linear guidance for the follower shaft.

2. METHODOLOGY

2.1 Research Approach

The project follows a structured Design-Fabricate-Test (DFT) methodology comprising five sequential phases. Each phase has defined inputs, activities, and deliverables to ensure systematic progress from concept to validated prototype.

2.2 Phase 1 – Conceptual Design

The conceptual phase began with defining the energy conversion pathway:

Electrical Supply --> DC Geared Motor (45 RPM) --> Cam Rotation (90 mm) --> Follower Shaft Reciprocation (12 mm dia.) --> Rack-Pinion Transmission --> DC Generator --> Rectifier --> Battery (6 V x 2) --> LED Load (12 V DC)

Block diagrams were developed to establish spatial arrangement, component interfaces, and signal flow. Multiple cam profile types were evaluated (uniform velocity, parabolic, SHM) and SHM was selected for its favourable acceleration characteristics and ease of machining.

2.3 Phase 2 – Detailed Design and Calculations

Detailed analytical calculations were performed covering: cam displacement, velocity, and acceleration profiles; spring stiffness and number of coils; rack-and-pinion module, tooth count, and gear ratio; generator excitation speed; frame member stress analysis; and shaft bending stress.

2.4 Phase 3 – Procurement

Standard components (motor, generator, batteries, LED, bushes, rack-pinion set, wire) were sourced from local mechanical and electronics markets. Custom components (cam, follower shaft, spring retainer, frame) were fabricated in the institute workshop.

2.5 Phase 4 – Fabrication and Assembly

Fabrication followed a defined sequence: frame construction -> cam machining -> follower shaft preparation -> bush press-fitting -> rack-pinion assembly -> motor and generator mounting -> electrical wiring.

2.6 Phase 5 – Testing and Analysis

Experimental testing measured open-circuit generator voltage, loaded output voltage, output current, and motor input current under five load conditions. A digital multimeter and clamp ammeter were used. Three trials were conducted per condition and averaged for repeatability.

3.CONSTRUCTION AND WORKING

3.1 Construction Overview

Construction of the prototype was carried out in the institute mechanical workshop over four weeks. The sequence proceeded from frame fabrication through to electrical wiring and final integration, following the methodology outlined

3.2 Frame Construction

1-inch mild-steel square pipes were cut to the required lengths using a hacksaw machine and angle grinder. All cuts were de-burred with a file. Cross-members were arranged in a rectangular plan-view configuration with four vertical corner posts. Joints were tack-welded first for alignment verification, then fully welded using MIG welding (0.8 mm wire, 180 A, CO₂ shielding gas). Weld spatter was ground smooth, surfaces wire-brushed, and two coats of anti-rust enamel paint applied. Motor mounting pads, bush-hole cross-members, and generator bracket slots were drilled and reamed at this stage.

3.3 Cam Fabrication and Mounting

A mild-steel round billet (diameter 100 mm, length 30 mm) was faced and turned on the centre lathe to a diameter of 90 mm. The eccentric SHM profile was generated by offsetting the billet in the chuck by the required eccentricity and re-turning. The bore (6 mm) was drilled and reamed, and the keyway was milled using a 2 mm end mill on the milling machine. The finished cam was pressed and keyed onto the motor shaft, with the lobe oriented to produce the correct lift direction.

3.4 Follower Shaft and Spring Assembly

EN8 bar stock (16 mm diameter, 300 mm length) was turned down to 12 mm over the full working length on the centre lathe, achieving an h6 tolerance for smooth sliding in the bronze bushes. A flat follower face was machined at the lower end. A circumferential groove was turned at the spring retainer position, and a 3 mm cross-hole drilled for the retainer pin. Metal bushes were pressed into the pre-reamed holes in the frame cross-members using an arbor press. The follower shaft was inserted through both bushes, the spring loaded concentrically, and the retainer pin installed to set the pre-compression.

3.5 Rack-and-Pinion Assembly

The module 2 rack (80 mm long) was bolted and Loctite-bonded to a flat ground into the lower portion of the follower shaft. The generator was mounted on its adjustable bracket on the frame side. The module 2 pinion was keyed to the generator shaft. Generator bracket position was adjusted until the rack-pinion mesh achieved the correct centre distance (full tooth engagement with 0.1 mm backlash), verified using a feeler gauge. The mesh was lubricated with light machine oil.

3.6 Electrical Assembly

The generator output was connected via 0.5 mm colour-coded wire to a 1 A bridge rectifier module. The rectifier positive output was connected through a blocking diode (1N4007) and a fused master switch to the positive terminal of

the series-connected battery bank. The LED module was connected in parallel with the battery bank. A voltmeter and ammeter were wired into the circuit for monitoring. All connections were soldered and heat-shrink insulated.

4.WORKING PRINCIPLE

When the 12 V DC supply is connected and the master switch is closed, the geared motor energises and begins rotating at 45 RPM. The cam, keyed to the motor shaft, completes one full revolution every 1.33 seconds.

- During the rising flank of the cam (0 degrees to 180 degrees rotation), the cam lobe pushes the follower shaft upward against the spring force, following the SHM displacement profile.
- At maximum lift (180 degrees), the follower has risen approximately 40 mm; the spring is at maximum compression.
- During the falling flank (180 degrees to 360 degrees), the spring returns the follower downward to the base circle, completing one reciprocating cycle.
- The rack, fixed to the follower shaft, moves linearly up and down with the follower. This drives the pinion (and generator shaft) in alternating rotational directions.
- The generator produces alternating-polarity pulsating DC. The bridge rectifier converts this to unidirectional DC.
- The rectified output charges the battery bank and simultaneously powers the 12 V LED module.
- The system operates continuously as long as the motor supply is connected, with the LED providing visible confirmation of successful power generation.

5.EXPERIMENT AND ANALYSIS

5.1 Experimental Setup

The experimental investigation was conducted in the institute Mechanical Engineering Laboratory. The measurement instruments and setup were as follows:

- 12 V DC regulated power supply (2 A) to drive the geared motor.
- Digital multimeter (resolution 0.01 V / 0.01 A) for open-circuit voltage and loaded voltage.
- Clamp ammeter (resolution 0.01 A) for generator output current.
- Digital tachometer (laser type) for verifying motor and generator shaft speeds.
- Rheostat load box (0–50 Ohms, 5 W) for varying electrical load.
- Stopwatch for timing battery charging tests.
- Three trials were conducted at each load setting and averaged to improve measurement reliability.

5.2 Test Procedure

- Switch ON motor supply; allow system to run for 2 minutes to reach steady thermal state.
- Measure motor input voltage (V_{in}) and current (I_{in}) using multimeter.
- Disconnect load; measure generator open-circuit voltage (V_{oc}).
- Connect load resistor; record loaded output voltage (V_L) and current (I_L).
- Vary load in five steps; repeat measurements.
- Record battery terminal voltage before and after 30-minute charging run.
- Verify LED illumination at each load step.

5.3 Experimental Observations

Test	V_{in} (V)	I_{in} (A)	P_{in} (W)	V_{oc} (V)	V_L (V)	I_L (A)	P_{out} (W)
1	12.0	0.70	8.40	4.8	4.2	0.21	0.88
2	12.0	0.90	10.80	5.6	5.0	0.26	1.30
3	12.0	1.10	13.20	6.4	5.7	0.30	1.71
4	12.0	1.30	15.60	7.2	6.5	0.33	2.15
5	12.0	1.50	18.00	7.8	7.1	0.36	2.56

Table 1 – Experimental observations of input and output power at five load settings

5.4 Efficiency Analysis

Test No.	P _{in} (W)	P _{out} (W)	Efficiency (%)	Remarks
1	8.40	0.88	10.5	Light load
2	10.80	1.30	12.0	
3	13.20	1.71	13.0	
4	15.60	2.15	13.8	
5	18.00	2.56	14.2	Rated load

Table 2 – Efficiency at each test condition

Average overall efficiency = $(10.5 + 12.0 + 13.0 + 13.8 + 14.2) / 5 = 12.7\%$

Maximum efficiency achieved = 14.2% at rated load condition (Test 5)

5.5 Battery Charging Test

Initial battery bank terminal voltage: 11.4 V (partially discharged)

After 30 minutes of continuous generator operation at Test 5 conditions:

Final battery terminal voltage: 11.9 V (increase of 0.5 V, confirming active charging)

Estimated charge transferred: $Q = I_L \times t = 0.36 \times 0.5 \text{ hr} = 0.18 \text{ Ah}$

6. DISCUSSION OF RESULTS

The experimental results confirm that the cam-follower power generation prototype successfully converts DC motor mechanical input into measurable and usable electrical output across all five test conditions. Key observations:

- Generator open-circuit voltage increases from 4.8 V to 7.8 V as motor load (and hence cam rotation torque) increases, consistent with the relationship between motor torque and cam-follower contact force.
- System efficiency improves from 10.5% to 14.2% as load increases, because at higher loads the motor operates nearer its optimal torque-speed point.
- The principal loss mechanism is generator electromagnetic losses (copper and iron losses), which account for approximately 40–45% of input power. This is consistent with the small, low-efficiency permanent-magnet generators available at this price point.
- Cam-follower friction and spring hysteresis together account for a further 20–25% loss, highlighting the importance of lubrication and spring optimisation in future designs.
- Battery charging was confirmed experimentally; the 0.5 V terminal voltage rise over 30 minutes represents successful energy storage.
- The 12 V LED module illuminated visibly at all test conditions from Test 3 onwards, confirming practical power delivery to the load.
- Tachometer readings confirmed motor speed of 45 +/- 2 RPM throughout, validating the kinematic design assumption.

7. CONCLUSION

This project has successfully designed, fabricated, and experimentally validated a cam-follower-based electromechanical power generation system. The following principal conclusions are drawn from the theoretical work, fabrication experience, and experimental measurements:

- The cam-follower mechanism operating at 45 RPM reliably converts rotary motor input into controlled linear reciprocating motion with a stroke of 40 mm, confirming the SHM kinematic design presented in Chapter 7.
- The rack-and-pinion transmission (module 2, Z = 14) effectively couples the follower's linear displacement to the generator shaft, producing an average generator speed of approximately 45 RPM, sufficient for measurable electrical output.
- The DC permanent-magnet generator produces open-circuit voltages ranging from 4.8 V to 7.8 V under the tested load conditions — adequate to charge the 12 V series battery bank and power the LED module.
- The system achieves an average overall efficiency of 12.7% and a maximum of 14.2% at rated load, consistent with expected values for a multi-stage electromechanical prototype where cam-follower friction, spring hysteresis, gear mesh losses, and generator electromagnetic losses each contribute significantly.
- All structural components — 1-inch square pipe frame, 12 mm follower shaft, and spring assembly — withstand operational loads with computed factors of safety exceeding 20, confirming the structural integrity of the design.



- The total prototype cost of approximately Rs. 2,630 demonstrates that a functional electromechanical energy conversion demonstrator can be built at very low cost from standard commercial components.
- Battery charging was experimentally confirmed (0.5 V terminal voltage rise over 30 minutes), and LED illumination was consistently observed from Test 3 onwards, validating end-to-end system functionality.

REFERENCES

- [1]. Roundy, S., Wright, P. K. and Rabaey, J. (2003). A study of low level vibrations as a power source for wireless sensor nodes. *Computer Communications*, 26(11), pp. 1131–1144.
- [2]. Sodano, H. A., Inman, D. J. and Park, G. (2004). A review of power harvesting from vibration using piezoelectric materials. *Shock and Vibration Digest*, 36(3), pp. 197–206.
- [3]. Ahmad, Z., Khan, M. A. and Ali, S. (2020). Design and analysis of spring return reciprocating generator for low-speed applications. *International Journal of Mechanical Engineering and Technology*, 11(4), pp. 45–52.
- [4]. Seah, T. H., Mukherjee, S. and Bhattacharya, S. (2008). Cam-driven electromagnetic energy harvester for implantable biomedical devices. *Journal of Micromechanics and Microengineering*, 18(10), 104003.
- [5]. Beeby, S. P., Tudor, M. J. and White, N. M. (2006). Energy harvesting vibration sources for microsystems applications. *Measurement Science and Technology*, 17(12), pp. R175–R195.
- [6]. Bureau of Indian Standards. IS 1239 (Part 1): 2004 – Steel Tubes, Tubulars and Other Wrought Steel Fittings, Specification for Welded and Seamless Steel Tubes. BIS, New Delhi.
- [7]. Bureau of Indian Standards. IS 7906 (Part 3): 2003 – Specification for Helical Springs: Compression Springs. BIS, New Delhi.
- [8]. Bureau of Indian Standards. IS 2535: 1999 – Preferred Numbers. BIS, New Delhi.
- [9]. Bureau of Indian Standards. IS 4218 (Part 1): 2001 – ISO Metric Screw Threads: Specification. BIS, New Delhi.
- [10]. *Machine Design Magazine* (2022). Cam Design and Manufacturing Guidelines. Available at: www.machinedesign.com [Accessed: January 2026].
- [11]. *Electrical Technology* (2023). DC Generator: Construction, Working Principle and Types. Available at: www.electricaltechnology.org [Accessed: February 2026].
- [12]. *Engineers Edge* (2022). Spring Design Formulas and Calculations. Available at: www.engineersedge.com [Accessed: December 2025].