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Design and Fabrication of Solar Operated Drilling Machine

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Abstract - Solar energy is one of the most abundant renewable energy sources available for sustainable power generation. This paper presents an experimental investigation of the conversion of solar energy into electrical energy and subsequently into mechanical energy using a photovoltaic panel and DC geared motor. A 12 V, 3 W polycrystalline solar panel was used to generate electrical energy under varying climatic conditions. The electrical output was measured and used to drive a 12 V DC motor with rated torque of 3 kg·cm and speed of 100 RPM. The mechanical power, mechanical energy, shaft work, and spindle speed were calculated using standard engineering relations. Experimental results show that maximum electrical power of 3.51 W and corresponding mechanical energy of 11.08 kJ were obtained under clear sky conditions. The study demonstrates that solar photovoltaic systems can effectively power mechanical devices and convert renewable solar energy into useful mechanical work.

Keywords: Solar energy, photovoltaic system, DC motor, mechanical energy, shaft work, renewable energy

1. INTRODUCTION

The increasing demand for energy and depletion of fossil fuels have led to the exploration of renewable energy sources. Solar energy is one of the most promising renewable energy sources due to its abundance, sustainability, and environmental friendliness. Photovoltaic (PV) systems convert solar radiation directly into electrical energy using semiconductor materials.

The electrical energy generated from solar panels can be used to power mechanical systems such as pumps, fans, drilling machines, and automation systems. Conversion of solar energy into mechanical energy is an important process in solar-powered engineering applications.

DC motors are commonly used for converting electrical energy into mechanical energy due to their simplicity, reliability, and ease of control. When powered by solar panels, DC motors enable solar-driven mechanical work without dependence on conventional electricity sources.

The objective of this study is to experimentally investigate the conversion of solar energy into electrical energy and subsequently into mechanical energy and shaft work using a photovoltaic panel and DC motor under different climatic conditions.

2. LITERATURE REVIEW

Duffie and Beckman (2013) explained the fundamental principles of solar radiation and photovoltaic energy conversion. Solanki (2015) discussed photovoltaic system performance and electrical power generation using solar panels.

Several researchers have investigated solar-powered motor systems. Nema and Nema analysed photovoltaic system performance under varying radiation conditions and demonstrated direct proportionality between solar radiation and electrical output.

Rattan (2019) described the relationship between torque, angular velocity, and mechanical power in rotating systems. These principles are used to calculate mechanical power and shaft work in DC motor systems.

Previous studies confirm that photovoltaic systems can effectively power mechanical systems such as water pumps and automation systems.

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3. METHODOLOGY

The energy conversion process in this study follows the sequence:

Solar radiation → Electrical energy → Mechanical energy → Shaft work

The following equations were used:

Solar electrical power:

$P = V \times I$

Mechanical power:

$P = T \times \omega$

Angular velocity:

$\omega = 2\pi N/60$

Mechanical energy:

$E = P \times t$

Torque conversion:

$T\,(N.m) = T(kg.cm) \times 9.81 \times 0.01$

Where:

P = Power (W)

V = Voltage (V)

I = Current (A)

T = Torque (N·m)

ω = Angular velocity (rad/s)

N = Speed (RPM)

t = Time (s)

4. EXPERIMENTAL SETUP

The experimental setup consists of:

Polycrystalline solar panel (12 V, 3 W)

DC geared motor (12 V, 100 RPM, 3 kg·cm torque)

Digital multimeter

Solar radiation measurement data

Load-free motor shaft

The solar panel was exposed to sunlight under different climatic conditions. The output voltage and current were measured, and the motor was operated using the generated electrical power.

5. CALCULATIONS

Motor torque conversion:

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$T=3\times9.81\times0.01=0.294$ N.m

Angular velocity:

$\omega= 2\pi\times100/60$

$\omega=10.47$ rad/s

Mechanical power:

$P= 0.294\times10.47$

$P= 3.08W$

Mechanical energy per hour:

$E= 3.08\times3600$

$E=11088$ J

Table: Solar Radiation vs Electrical and Mechanical Output

Climatic Condition	**Solar radiation(W/m2)**	**Electrical Power (W)**	**Mechanical Energy (J)**	**Spindle Speed (RPM)**
Clear winter noon	1000	3.51	11088	100
Warm sunny day	900	2.92	10512	95
Mild sunny day	800	2.61	9396	85
Partly cloudy	600	1.96	7056	64
Cloudy sky	400	1.33	4788	43
Rainy weather	200	0.70	2520	23

6. RESULTS AND DISCUSSION

Results show that electrical power output depends directly on solar radiation intensity. Maximum electrical power of 3.51 W was obtained under clear sky conditions. Mechanical energy output depends on available electrical energy and motor characteristics.

Spindle speed decreases under low radiation conditions due to reduced mechanical power availability. This confirms that solar radiation significantly affects mechanical performance.

The results demonstrate effective conversion of solar energy into mechanical work using photovoltaic systems.

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6.1 Electrical Power generation at various solar radiation

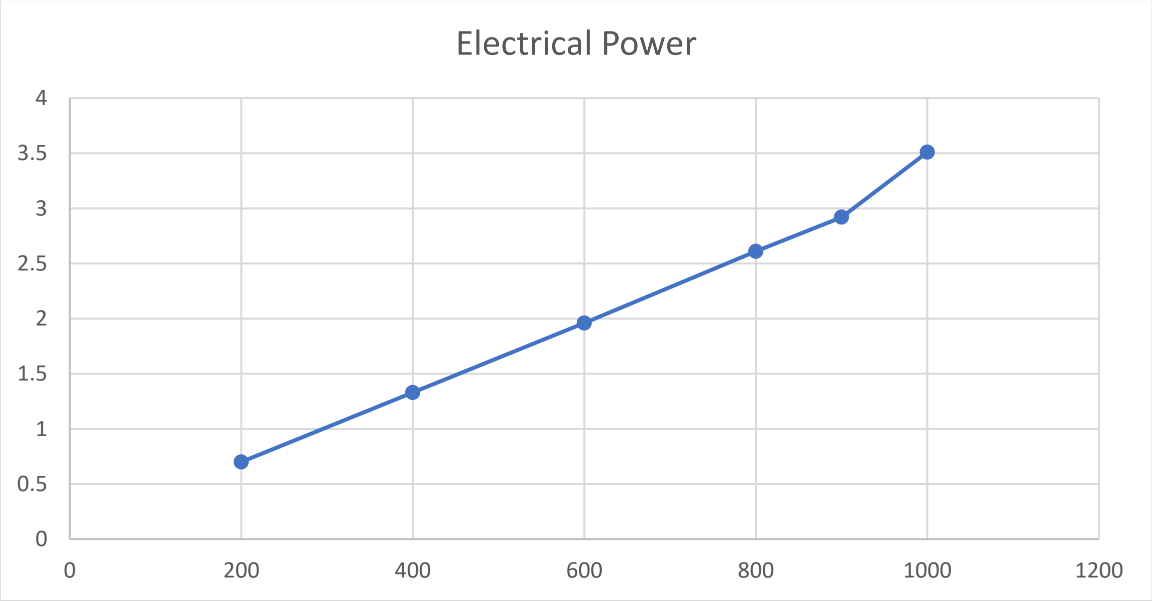
Graph Title:

Solar Radiation vs Electrical Power

Axes:

X-axis: Solar Radiation (W/m²)

Y-axis: Electrical Power (W)



- The graph shows how electrical power output of the solar panel changes with solar radiation.
- As solar radiation increases from 200 → 1000 W/m², electrical power increases from 0.70 → 3.51 W.
- The relationship is almost linear (directly proportional).
- The graph is increasing because of the photovoltaic effect.

Reason 1: More Sunlight = More Energy

- Solar radiation represents the amount of sunlight falling on the panel.
- Higher radiation means more energy available per unit area.

Reason 2: Increase in Photons

- Sunlight consists of photons.
- When radiation increases:

More photons strike the solar cells

More electrons are excited

This increases electric current (I)

Reason 3: Power Equation

$P = V \times I$

- Voltage (V) changes slightly
- Current (I) increases significantly

Therefore, power increases

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Reason 4: Direct Proportionality

$P \propto G$

Where:

- P= Power
- G= Solar radiation

It is Not Perfectly Straight

Reason 1: Temperature Effect

- At higher radiation, panel temperature increases
- High temperature reduces efficiency slightly

Reason 2: Material Losses

- Internal resistance of solar cells
- Electrical losses in connections

Reason 3: Environmental Factors

- Dust
- Angle of sunlight
- Minor shading

6.2 Electrical power at various spindle speed

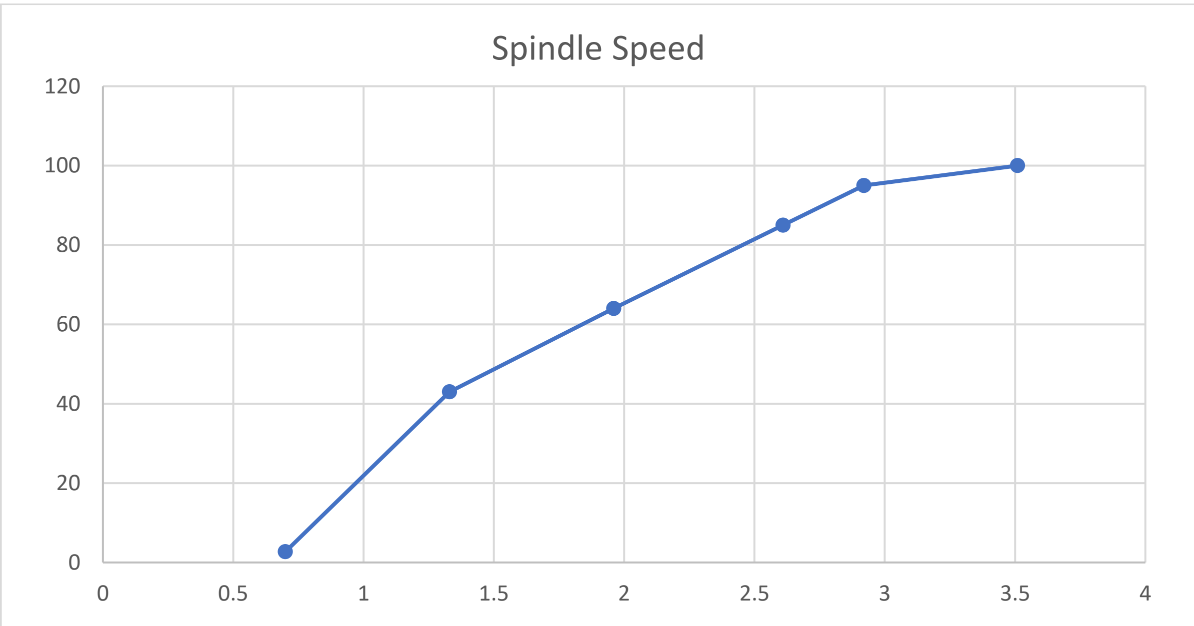
Graph Title:

Electrical Power vs Spindle Speed

Axes:

X-axis: Electrical Power (W)

Y-axis: Spindle Speed (RPM)



- The graph shows how spindle speed of the DC motor varies with electrical power input.

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- As electrical power increases from 0.70 W to 3.51 W, spindle speed increases from 23 RPM to 100 RPM.
- The relationship is direct (increasing trend) but not perfectly linear.

Reason 1: More Electrical Power → More Motor Output

Electrical power supplied to the motor:

$P=V\times I$

- As power increases, the motor receives more energy per second
- This allows the motor to rotate faster

Hence, spindle speed increases

Reason 2: Relation Between Power and Speed

$P=T\times \omega$

Where:

T= Torque

ω= Angular speed

For a geared motor:

Torque is approximately constant

So: $\omega \propto P$

Speed increases with power

Reason 3: Overcoming Losses at Low Power

At low power (0.7 W):

- Motor struggles to overcome:

  Friction

  Internal resistance

- So, speed is very low (23 RPM)

As power increases:

- These losses are overcome
- Speed rises quickly

The graph is not perfectly linear

Reason 1: Motor Saturation (Speed Limit)

- The motor is rated at 100 RPM
- After ~2.9 W, speed increases very slowly

Graph starts flattening near the top

Reason 2: Mechanical Losses

- Gear friction

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- Bearing losses
- Air resistance

These reduce efficiency at higher speeds

Reason 3: Voltage Limitation

- The motor is designed for 12 V
- Even if power increases slightly, speed cannot increase beyond design limit

7. CONCLUSION

- The study investigated the conversion of solar energy into electrical and mechanical energy using a photovoltaic panel and DC motor.
- Maximum mechanical energy of 11.08 kJ was obtained under clear sky conditions.
- System proves feasibility of solar-powered mechanical applications.
- Future work can focus on energy storage integration and improved solar panel efficiency.

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