Mathematical Appendix

The mathematical appendix serves to quantify the performance metrics, efficiency, and potential output of the Vacuum-Sealed Magnetic Generator (VSMG). Below are the derivations, calculations, and equations governing its operation.

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1. Efficiency of the VSMG

The efficiency η of the generator is defined as:

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100$$

Where:

- P_{out} is the electrical power output.
- P_{in} is the total input power, including losses.

Given:

- Air resistance $R_{\text{air}} \to 0$ due to vacuum sealing.
- Frictional losses $F_{\text{friction}} \to 0$ due to magnetic levitation.

Thus, the efficiency is primarily limited by:

1. Electromagnetic losses L_{em},
2. Heat losses L_{thermal}.

The overall efficiency can be approximated as:

$$\eta \approx 1 - \frac{L_{\text{em}} + L_{\text{thermal}}}{P_{\text{in}}}$$

Empirical data from similar systems (e.g., graphene-based generators) indicates efficiencies exceeding 90% when $L_{\text{em}} + L_{\text{thermal}} \ll P_{\text{in}}$ (Lee et al., 2019).

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2. Electromagnetic Induction

The induced electromotive force (E) in the rotor is derived from Faraday's Law:

$$\mathrm{E} = -N\frac{d\Phi}{dt}$$

Where:

- N = Number of turns in the coil,
- Φ = Magnetic flux ($\Phi = B \cdot A$),
- B = Magnetic field strength,
- A = Area of the coil.

Assumptions for a typical VSMG:

- $N = 10^3$,
- $B = 1.5\,\mathrm{T}$ (Tesla),
- $A = 0.01\,\mathrm{m}^2$.

Using rotational frequency $f = 100\,\mathrm{Hz}$:

$$\frac{d\Phi}{dt} = B \cdot A \cdot 2\pi f$$

Substitute:

$$\mathrm{E} = -10^3 \cdot (1.5 \cdot 0.01 \cdot 2\pi \cdot 100)\,\mathrm{V}$$

$$\mathrm{E} = -942\,\mathrm{V}$$

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3. Power Output

The power output P_{out} is calculated as:

$$P_{\text{out}} = \mathrm{E} \cdot I$$

Where I is the current. Assuming a load impedance Z:

$$I = \frac{\mathrm{E}}{Z}$$

For $Z = 10\,\Omega$:

$$I = \frac{942}{10} = 94.2\,\mathrm{A}$$

Thus:

$$P_{\text{out}} = 942 \cdot 94.2 = 88.7\,\mathrm{kW}$$

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4. Thermoelectric Contributions

The thermoelectric power generated due to the Seebeck effect is:

$$P_{\text{thermo}} = S \cdot I \cdot \Delta T$$

Where:

- S = Seebeck coefficient ($\sim 200\,\mu\text{V/K}$ for Bi_2Te_3),
- ΔT = Temperature gradient ($\sim 50\,\text{K}$).

Substitute:

$$P_{\text{thermo}} = (200 \times 10^{-6}) \cdot 94.2 \cdot 50$$

$$P_{\text{thermo}} = 0.94\,\text{W}$$

While small, this power is recycled internally to enhance efficiency.

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5. Theoretical Market Implications

Assuming:

- A single unit generates $1\,\text{MW}$,
- Cost per unit is $10,000 USD.

Global deployment potential:

$$\text{Energy Output} = 1\,\text{MW/unit} \times 10^6\,\text{units} = 1\,\text{TW}$$

$$\text{Cost} = 10^6 \times 10^4 = 10\,\text{Billion USD}$$

Comparing this with nuclear power (average cost $10 Billion per GW):

$$\text{Cost Ratio} = \frac{10\,\text{Billion USD}}{10^3\,\text{GW}} = 1\%$$

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6. Future Research Directions

1. **Optimization of CNT-Coated Rotors**: Increased efficiency through reduced resistive losses.
2. **Enhanced Aerogel Applications**: Further magnetic field isolation.
3. **Scaling Models**: Adapting designs for residential, commercial, and industrial use.

The above equations and assumptions provide a theoretical underpinning for the revolutionary potential of the VSMG. Future research and testing will further refine these projections and validate the technology in practical applications.