Supporting Information

Design and investigation of a magnetic coupling piezoelectric inertial energy harvesting system for low-power wireless sensors in intercity bus

Zhen Zhao [a&], Xiaohui Zhang [a&], Baifu Zhang [b], Haichuan Cui [c], Xinjun Li [a], Enyu He [a]*

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Figures

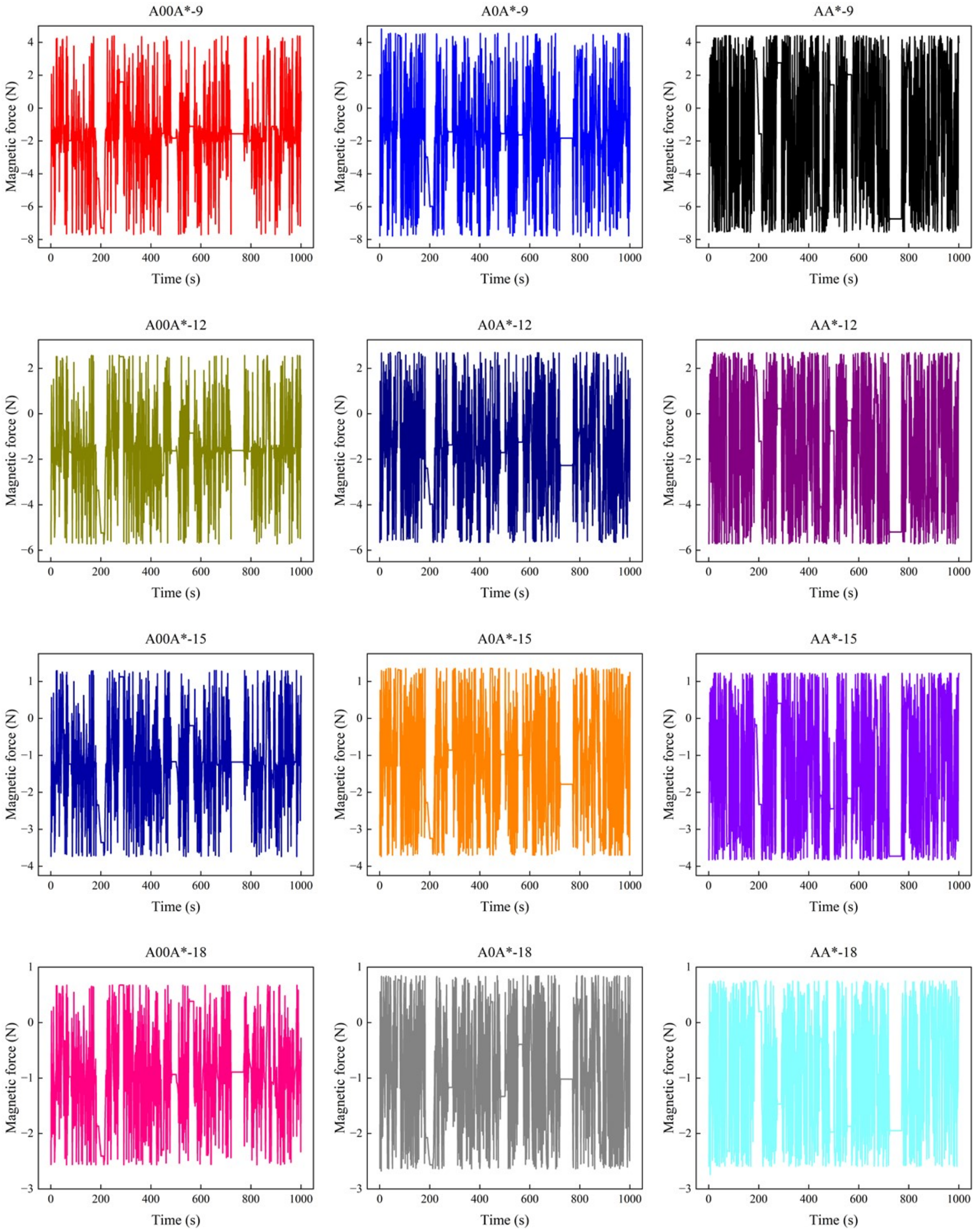

Fig. S1 Magnetic force curve under condition three

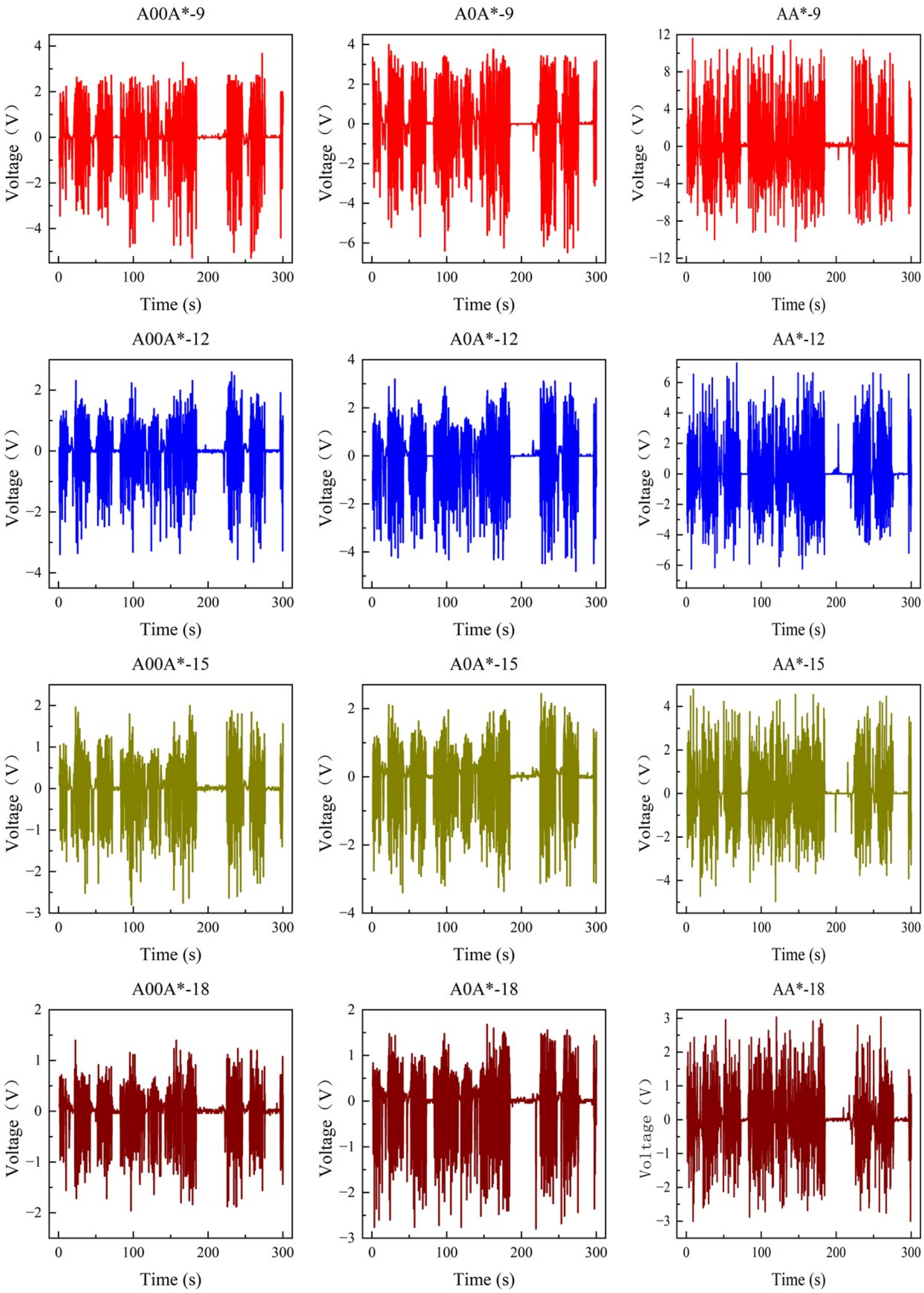

Fig. S2 The voltage variation curves with condition 3

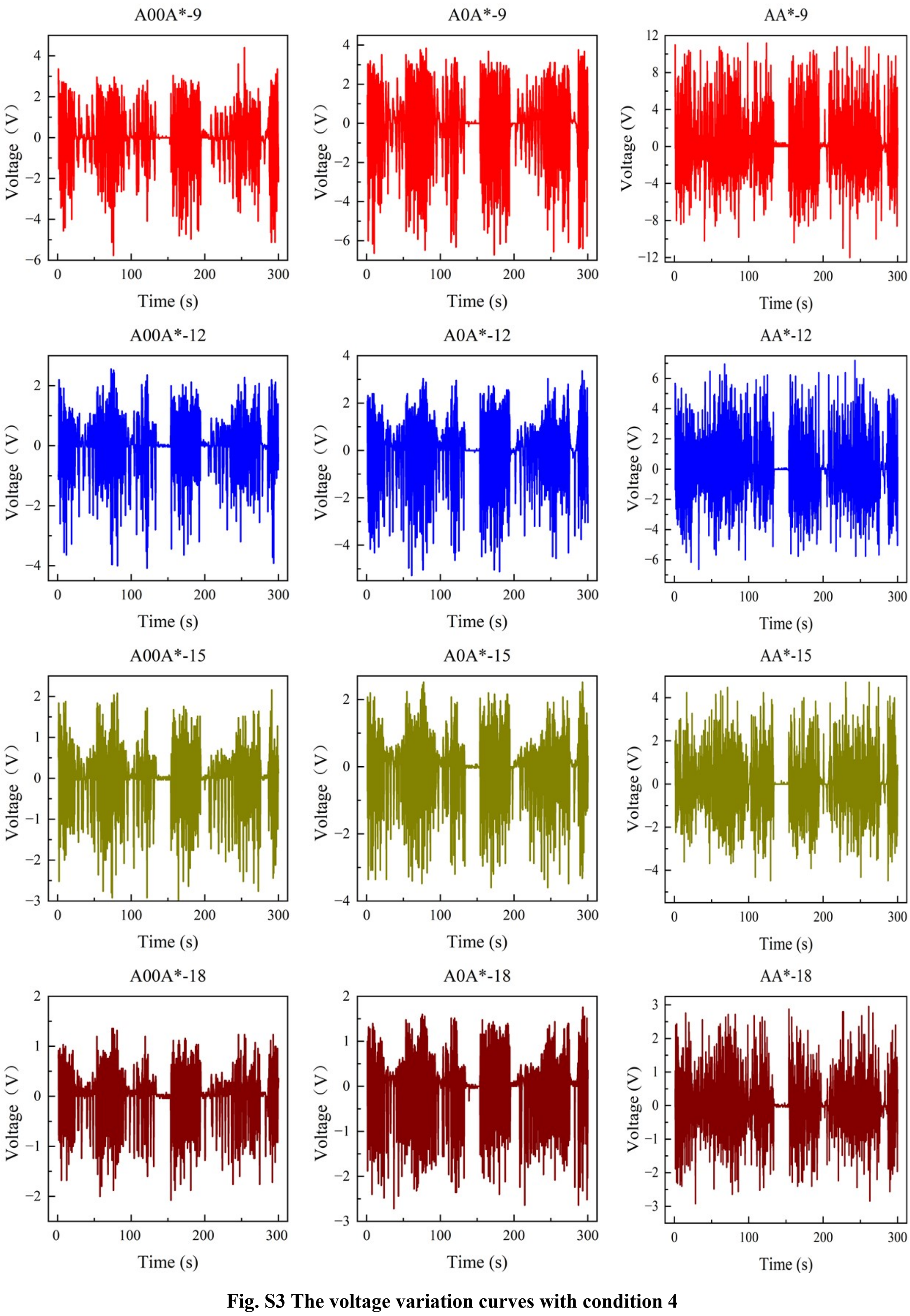

Fig. S3 The voltage variation curves with condition 4

Note. S1

Kinetic energy input model

External torque is primarily utilized in three components:

$$J \cdot \ddot{\theta}(t) = \mathrm{m} \cdot l_0 \cdot \ddot{x}(t) \cdot \cos(\theta_0(t)) = T_1 + T_2 + T_3 \tag{1}$$

Among these components, T_1 represents the equivalent torque of each system component, T_2 denotes the gear meshing damping torque, and T_3 refers to the magnetic torque resulting from the interaction between magnet A and magnet B.

$$T_1 = [J_0 + 3 \times n_0^2 \times (J_1 + J_2 + J_3 + J_4 + n_1^2 \times (J_5 + J_6)) + n_0^2 n_1^2 n_2^2 \times (J_7 + J_e)] \times \ddot{\theta}_0(t) \tag{2}$$

Among these parameters, J_0 represents the rotational inertia of the mass ball and the ring gear, while J_1, J_2, J_3, J_4, J_5, J_6, and J_7 correspond to the moments of inertia of gears 1 through 7. Additionally, J_e indicates the moment of inertia of the rotor.

$$J_s = J_0 + 3 \times n_0^2 \cdot (J_1 + J_2 + J_3 + J_4 + n_1^2 \cdot (J_5 + J_6)) + n_0^2 n_1^2 n_2^2 \cdot (J_7 + J_e) \tag{3}$$

The gear meshing damping torque of the system is defined as:

$$T_2 = 3 \times (C_{mr} + C_{m1} + 2 \times C_{m3} + C_{m6}) \cdot \ddot{\theta}_0(t) \tag{4}$$

Among these parameters, C_{mr} represents the meshing damping coefficient between the ring gear and gear 1, C_{m1} denotes the meshing damping coefficient between gears 1 and 2, C_{m3} corresponds to the meshing damping coefficient between gears 3 and 5, and C_{m6} indicates the meshing damping coefficient between gears 6 and 7.

$$C_{ms} = C_{mr} + C_{m1} + 2 \times C_{m3} + C_{m6} \tag{5}$$

The magnetic torque is:

$$T_3 = n_0 n_1 n_2 \cdot C_e \cdot \dot{\theta}_0(t) \tag{6}$$

$$n_0 = z_r/z_1, n_1 = z_3/z_5, n_2 = z_6/z_7 \tag{7}$$

Among these parameters, C_e indicates the system's magnet damping coefficient, while z_r, z_1, z_3, z_5, z_6, and z_7 denote the tooth counts of the ring gear, gear 1, 3, 5, 6, and 7, respectively.

Note. S2

Magnetic force model

$$\phi_x^N = -U_{mn}^N W_{pq}^N \ln(r^N - U_{mn}^N) - V_{ul}^N W_{pq}^N \ln(r^N - V_{ul}^N) + U_{ij}^N V_{ul}^N \tan^{-1}\left(\frac{U_{ij}^N V_{ul}^N}{r^N W_{pq}^N}\right) - r^N W_{pq}^N \tag{8}$$

where U_{mn}^N, V_{ul}^N, W_{pq}^N and r^N can be calculated as:

$$\begin{cases} U_{mn}^N = d_x^N + (-1)^n L - (-1)^m L^N \\ V_{ul}^N = d_y^N + (-1)^l W - (-1)^u W^N \\ W_{pq}^N = d_z^N + (-1)^q H - (-1)^p H^N \\ r^N = \sqrt{(U_{mn}^N)^2 + (V_{ul}^N)^2 + (W_{pq}^N)^2} \end{cases} \tag{9}$$

In this context, the parameters the L^N, W^N and H^N denote the extent, breadth, and depth of magnet A, respectively. Similarly, the terms L, W, and H correspond to the extent, breadth, and depth of magnet B. The orthogonal projection distances of magnets A and B along the x, y, and z axes within the Cartesian coordinate system are represented by d_x^N, d_y^N, and d_z^N, respectively.

Magnets A and B are attached on the rotor and the PZT unit, respectively, and are situated within the x-y plane. Consequently, the perpendicular separation from magnet A to magnet B can be described as follows:

$$\begin{cases} d_x^N = r_m + d_{x0}^N - r_m \cos(\omega t - \varphi^N) - x(t) \\ d_y^N = r_m \sin(\omega t - \varphi^N) \\ d_z^N = 0 \end{cases} \tag{10}$$

In this context, r_m represents the radius of gyration of magnet A, which is fixed on the rotor; d_{x0}^N represents the original distance in the designated direction from magnet A to magnet B; $x(t)$ indicates the displacement of magnet B; φ^N refers to the angular change of magnet A at its initial position; and q signifies the number of magnet A units present.

$$\varphi^{i+1} = \varphi^i + 2\pi / q \tag{11}$$