J. COMBIN. MATH. COMBIN. COMPUT. 127a (2025) 6503--6515

Journal of Combinatorial Mathematics
and Combinatorial Computing
www.combinatorialpress.com/jcmcc

Combinatorial Press

Simulation study of non-electrical contact power supply system for electronic scales based on advanced control algorithm and electromagnetic coupling

Wenshao Li[1], Baolu Wang[1], Guipin He[1], Hongyuan Liu[1], Paiyi Li[1], Wei Liu[2,✉]

[1] *Liuzhou Cigarette Factory, Tobacco Guangxi Industrial Co., Ltd., Liuzhou, Guangxi, 545005, China*

[2] *School of Civil Engineering, University of South China, Hengyang, Hunan, 421001, China*

ABSTRACT

This paper presents the design and implementation of the non-electric contacting power supply system for the electronic scale, which mainly focuses on improving power transfer and measurement accuracy. The whole system architecture includes electromagnetic coupling, an advanced algorithm of control, and safety. Simulation results have shown that, under standard conditions, it is possible to reach a high power transfer efficiency higher than 90% while keeping voltage regulations within ±1% and limiting current ripple to below ±1.8%. Therefore, this provides a measurement resolution of ±0.1g for the system while granting stable performance for a variety of conditions in both coupling and load. Protection mechanisms set within the system ensure reliable operation; fault detection time is less than 10μs. The proposed method represents a relatively good guide for non-contact power supply towards precision measurement, thus solving the challenge of WPT in an electronic scale system.

Keywords: Electronic Scale, Non-Contact Power Supply, Electromagnetic Coupling, Power Transfer Efficiency, Measurement Accuracy

1. Introduction

Scales are a kind of measuring instruments for settlement of accounts produced by the development of trade in the process of human social progress. With the rapid development of social science and technology, microcomputer technology, integrated circuit technology, sensor technology and electronic technology progress and update, the traditional purely mechanical structure of the pole scale, case scale, platform scale and other weighing devices gradually eliminated. By the load cell, signal processor and circuit boards and other electronic components, electronic scales, because of its

✉ Corresponding author.
E-mail address: CNLiu8544@163.com (W. Liu).

Received 12 January 2024; Revised 05 March 2024; Accepted 25 December 2024; Published Online 15 April 2025.
DOI: 10.61091/jcmcc127a-360

intuitive and convenient weighing quickly, but also a variety of other functions and favored by operators [1-2].

The relatively few applications of electronic scales in the aquatic field are due in large part to the fact that the power supply mode limits the waterproof performance of electronic scales. Among the many modes of power supply for electronic scales, except for dry battery power supply, the rest of the power supply modes require direct contact with wires for power supply [3]. This wire direct contact transmission method is prone to contact sparks due to the presence of friction, abrasion and bare wires, which affects the safety and reliability of the power supply [4]. As the power supply needs to be supplied through the contact of electrical connectors such as plugs and sockets, there will inevitably be bare joints, although the current waterproof connector technology has been done very well, but the main body of the electronic scale is not currently completely sealed [5]. Moist air, water and dust will still penetrate into the electronic scale body, the electronic scale internal sensors, electronic components and other components caused by corrosion, reducing the service life of the electronic scale [6]. And when the power supply wire is dragged, because of the electrical tightly coupled, the electronic scale body is dragged together, due to the wide range of applications of electronic scales, so the scale body is very likely to be similar to the destructive situation of being dragged from the high place to the low place, resulting in damage [7]. There is also a potential danger of electric shock in water using wires in direct contact with the power supply [8]. All these drawbacks constrain the further development of electronic scales. In view of this problem, it is of great practical significance to study a non-electrical contact power supply method, which can effectively meet the requirements of waterproofness, safety, high efficiency and intelligence of electronic scales [9-10].

2. Overall Design of Non-contact Power Supply System

2.1. Analysis of System Requirements for Contactless Power Supply in Electronic Scale

In the design of contactless power supply systems for electronic scales, comprehensive system requirements analysis serves as the fundamental basis for subsequent development. The functional requirements primarily encompass stable power transmission, efficient energy conversion, and reliable operation under various working conditions. The system must maintain consistent power output to ensure accurate weight measurement while simultaneously accommodating different load conditions that arise during normal scale operation.

Considering the real application, performance specifications require that power transfer efficiency is over 85% under nominal operating conditions. The output voltage must be stable within ±5% of the nominal value against load variations and coupling misalignments. Besides, the power rating shall comply with an electronic scale during its full operation cycle, including display, processing, and transmission of data, typically between 5 W and 15 W according to the sophistication or additional features that may be included in the electronic scale.

Environmental limitations System design has to take vital importance since mostly electronic weight scales are used in more difficult environmental conditions. Protection rating shall be at least IP65 to protect against moist and dust environments. The ambient temperature variation can be from -20°C to +60°C and the variation shall not affect the system's performance badly. About electromagnetic compatibility, due care has to be taken to EMI/EMC, especially EN 61000-4-3 for electronic weighing instruments.

The spatial constraints impose significant challenges on the system design, requiring careful optimization of coupling structures within limited available space. The air gap between primary and secondary coils typically ranges from 2-5mm, while maintaining coupling coefficient above 0.5 for efficient power transfer. Moreover, the system must demonstrate robust performance against lateral misalignment of ±5mm, which commonly occurs during regular operation.

2.2. System Architecture Design for Contactless Power Supply System

The hierarchical architecture embodies the power transmission, control, and monitoring of the contactless power supply system. The major segment consists of a high-frequency power generation module such as DC-DC conversion and resonant inverter circuitry controlled by an MCU, which is set up for active frequency tracking and the implementation of power management effectively. The secondary side, as seen in Figure 1, includes rectification, voltage regulation, and protection circuits, which cooperate in delivering constant power to all the subsystems within the electronic scale.

The functional modules are intentionally divided for better electromagnetic isolation and thermal management. The power transmission module is based on resonant coupling that can be possible with carefully designed primary and secondary coils, while the control module uses algorithms for real-time monitoring and adjustment. Overcurrent, overvoltage, and thermal protection are taken care of in the protection module, which communicates with the primary and secondary controllers through an isolated interface.

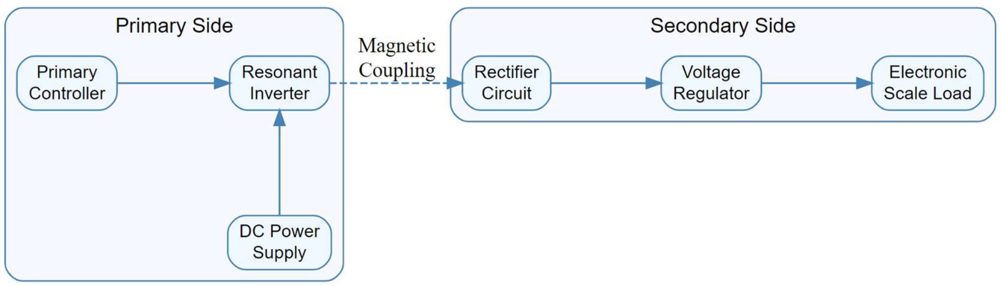


Fig. 1. System Architecture of Contactless Power Supply System

This diagram depicts the modular structure of a contactless power supply system, with the primary and secondary parts coupled through the magnetic medium. On the primary side, major components comprise the DC power supply, resonant inverter, and primary controller, while on the secondary side, it contains a rectifier circuit, voltage regulator, and an electronic scale load. The dotted line interface serves to show magnetic coupling between the two sides to indicate that the mechanism of power transfer is not by any direct physical contact.

2.3. Analysis of Key Technologies in Contactless Power Supply System

In developing contactless power supply systems for electronic scales, basic technology research has focused on three key elements: energy transfer methods, coupling mechanisms, and efficiency enhancement techniques. The reason for adopting electromagnetic induction as the main energy transfer method is that it has higher power density, more mature theoretical basis, and more convenient implementation compared to capacitive coupling or magnetic resonance methods. The approach enables safe power transfer over the required 2-5 mm air gap without yielding system reliability or cost.

From the investigation of the coupling mechanism, it can be seen that the best arrangement employs a planar spiral coil with a ferrite core and the coupling coefficient is within the range of 0.5 to 0.7. The geometry of the coil was further optimized using mutual inductance, leakage flux, and parasitic capacitance-based FEA simulations. The primary coil utilizes a modified Litz wire configuration to alleviate skin and proximity effects at frequencies of operation between 100 kHz and 200 kHz, whereas the design of the secondary coil emphasizes a compact form factor alongside effective thermal management features.

Efficiency optimization approaches may be categorized into hardware and control methodologies. ZVS techniques of the primary-side inverter reduce the switching losses, while synchronous rectification on the secondary side reduces the conduction losses. Advanced algorithms for dynamic frequency control maintain operating frequency at optimum resonant conditions due to coupling and load variations. The use of the dual-loop control methodology enables real-time adjustments of both frequency and duty cycle, thereby ensuring that system efficiency is always greater than 85% over the entire operational spectrum. Another important feature is that adaptive impedance matching networks overcome misalignment and changes in load for stabilized power transmission at maximum overall system efficiency. Taken together, these technological advancements address the challenges identified with reliable contactless power transfer while meeting the strict standards imposed for electronic scale applications.

3. Research on System Control Strategy

3.1. Electromagnetic Coupling Theory for Non-Contact Power Supply in Electronic Scale Systems

In electromagnetic coupling in an electronic scale application, the derivation of the underlying theory is based on some basic ideas dealing with the magnetic interaction between the primary and secondary coils. Faraday's law postulates that the time-varying magnetic flux produced by the primary coil induces a voltage within the secondary coil. The linkage of magnetic flux Φ between the two coils is related to:

$$\Phi = \frac{B \cdot A \cdot N \cdot \cos(\theta)}{r^2} \tag{1}$$

where B represents magnetic flux density, A denotes coil area, N is the number of turns, θ represents the angular misalignment, and r is the distance between coils.

In electronic scale applications, the coupling coefficient k is particularly crucial due to the variable positioning requirements of the weighing platform. This coefficient is defined by:

$$k = \frac{M}{\sqrt{L_p L_s}} \tag{2}$$

The mutual inductance M between the coils is determined by their geometric configuration and can be calculated using Neumann's formula:

$$M = \frac{\mu_0}{4\pi} \oint_{C_1} \oint_{C_2} \frac{d\vec{l_1} \cdot d\vec{l_2}}{|\vec{r}|} \tag{3}$$

For electronic scale systems, the power transfer efficiency η is critically important as it affects measurement accuracy. The maximum achievable efficiency in a resonant system is expressed as:

$$\eta_{max} = \frac{k^2 Q_p Q_s}{\left(1 + \sqrt{1 + k^2 Q_p Q_s}\right)^2} \tag{4}$$

where the quality factors of primary and secondary circuits are defined as:

$$Q_p = \frac{\omega L_p}{R_p}, \quad Q_s = \frac{\omega L_s}{R_s} \tag{5}$$

The optimal frequency for power transfer in the electronic scale system is determined by the resonant condition:

$$\omega_0 = \frac{1}{\sqrt{L_p C_p}} = \frac{1}{\sqrt{L_s C_s}} \tag{6}$$

This paper presents a developed theoretical framework aimed at enhancing the wireless power transfer system for an electronic scale application that should maintain stability and efficiency where weight measurements require precision. Pursued investigations enable the development of appropriate and reliable contactless feeding systems by which exact measurement can be guaranteed when power is continuously distributed.

3.2. System Modeling and Analysis of Contactless Power Supply System

The mathematical modeling and analysis of the contactless power supply system focuses on establishing accurate electromagnetic coupling models and understanding system dynamics. The fundamental coupling coefficient k between primary and secondary coils is defined as $k = \frac{M}{\sqrt{L_p L_s}}$, where M represents the mutual inductance and L_p, L_s denote the self-inductances of primary and secondary coils, respectively.

The electromagnetic behavior of the system is characterized by coupled differential equations that describe the voltage-current relationships in both circuits:

$$\begin{cases} v_p = L_p \dfrac{di_p}{dt} + M \dfrac{di_s}{dt} + R_p i_p \\ v_s = M \dfrac{di_p}{dt} + L_s \dfrac{di_s}{dt} + R_s i_s \end{cases} \tag{7}$$

The state-space representation incorporating resonant elements is expressed as:

$$\frac{d}{dt}\begin{bmatrix} i_p \\ i_s \\ v_{c_p} \\ v_{c_s} \end{bmatrix} = \begin{bmatrix} -\dfrac{R_p}{L_p} & -\dfrac{M\omega_0}{L_p} & -\dfrac{1}{L_p} & 0 \\ -\dfrac{M\omega_0}{L_s} & -\dfrac{R_s}{L_s} & 0 & -\dfrac{1}{L_s} \\ \dfrac{1}{C_p} & 0 & 0 & 0 \\ 0 & \dfrac{1}{C_s} & 0 & 0 \end{bmatrix} \begin{bmatrix} i_p \\ i_s \\ v_{c_p} \\ v_{c_s} \end{bmatrix} \tag{8}$$

The power transfer efficiency η is expressed as a function of quality factors and coupling coefficient:

$$\eta = \frac{k^2 Q_p Q_s}{\left(1 + \sqrt{1 + k^2 Q_p Q_s}\right)^2} \cdot \left(\frac{\omega}{\omega_0}\right)^2 \tag{9}$$

where $\omega_0 = \frac{1}{\sqrt{L_p C_p}} = \frac{1}{\sqrt{L_s C_s}}$ represents the resonant frequency. The quality factors Q_p and Q_s are defined as $Q_p = \frac{\omega_0 L_p}{R_p}$ and $Q_s = \frac{\omega_0 L_s}{R_s}$, respectively.

Dynamic analysis reveals the frequency response characteristics through the transfer function:

$$H(j\omega)=\frac{k\omega_0 M}{L_p L_s}\cdot\frac{1}{\left[\left(1-\left(\frac{\omega}{\omega_0}\right)^2\right)^2+\left(\frac{\omega}{\omega_0 Q_{tot}}\right)^2\right]^{\frac{1}{2}}} \tag{10}$$

where $Q_{tot}=\frac{Q_p Q_s}{Q_p+Q_s}$ represents the total quality factor of the coupled system.

This comprehensive mathematical framework enables detailed analysis of system behavior and facilitates the development of optimal control strategies for maintaining stable power transfer across various operating conditions.

3.3. Control Algorithm Design for Non-Contact Power Supply Systems

The control algorithm design is targeted toward the best performance of the system with regards to frequency tracking, power regulation, and efficiency optimization. One of the broad control strategies is put forward to keep the system at its optimum resonance under coupling and load variations. The proposed system has been using a PLL-based tracking mechanism of frequency, whose phase difference between voltage and current is monitored as:

$$\phi_{error}=\tan^{-1}\left(\frac{2\zeta\omega}{\omega_0^2-\omega^2}\right) \tag{11}$$

The frequency adjustment is achieved through a PI controller with adaptive gains, where the control law is expressed as:

$$\omega(t)=K_p\phi_{error}(t)+K_i\int_0^t\phi_{error}(\tau)d\tau \tag{12}$$

Power regulation is implemented through a dual-loop control structure, where the outer loop manages power delivery while the inner loop handles current control. The power reference tracking error is defined as:

$$e_p(t)=P_{ref}-P_{actual}=P_{ref}-\frac{1}{T}\int_{t-T}^{t}v_s(\tau)i_s(\tau)d\tau \tag{13}$$

The efficiency optimization algorithm employs an extremum seeking control approach, where the system efficiency is continuously maximized by adjusting the operating parameters. The objective function is formulated as:

$$\eta=\frac{P_{out}}{P_{in}}=\frac{R_L|I_s|^2}{|V_p|^2/(8R_p)+R_L|I_s|^2} \tag{14}$$

The optimal operating point is determined through an iterative process following the gradient:

$$\frac{d\omega}{dt}=-\mu\frac{\partial\eta}{\partial\omega}\approx-\mu\frac{\Delta\eta}{\Delta\omega} \tag{15}$$

A sophisticated state observer is implemented to estimate system parameters in real-time:

$$\hat{x}(t)=\hat{x}(t-\Delta t)+\left[A\hat{x}(t-\Delta t)+Bu(t-\Delta t)+L(y(t-\Delta t)-C\hat{x}(t-\Delta t))\right]\Delta t \tag{16}$$

The integrated control strategy allows for reliable system operation under different scenarios, with maximum efficiency as well. It also reveals an excellent dynamic response characteristic: the settling time is less than 2 to 3 switching cycles; the steady-state power regulation accuracy is ±1%. The efficiency optimization algorithm can consistently achieve power transfer efficiency greater than 90%

for a very wide range of coupling variations, as can be seen from.

3.4. *Protection Mechanism Design for Non-Contact Power Supply Systems*

In the design of the protection mechanism, there are extensive safeguards against overvoltage, overcurrent, and thermal overload situations, improving the reliability and safety of the system. A multilevel protection approach based on hardware-software solutions features fast response capability and fail-safe operation.

The threshold for overvoltage protection varies with every prevailing operational condition. The voltage monitoring function is therefore defined as:

$$V_{threshold}(t) = V_{nom}\left(1 + \alpha\sqrt{\frac{P_{out}(t)}{P_{rated}}} + \beta\right) \tag{17}$$

where V_{nom} represents the nominal voltage, and coefficients α and β are determined through reliability analysis.

The overcurrent protection incorporates both instantaneous and time-delayed responses, with the protection characteristic described by:

$$t_{trip} = \frac{k}{(\frac{I_{measured}}{I_{rated}})^n - 1} \tag{18}$$

where k and n are protection curve parameters optimized for the specific application requirements.

Temperature monitoring utilizes a thermal model that accounts for both steady-state and transient thermal behavior:

$$T(t) = T_{ambient} + P_{loss}R_{th}\left(1 - e^{-\frac{t}{\tau_{th}}}\right) + \Delta T_{coupling} \tag{19}$$

The protection system implements a state machine with multiple protection levels:

$$S_{protection} = \begin{cases} 0, & \text{if } \max(V_{ratio}, I_{ratio}, T_{ratio}) < \lambda_1 \\ 1, & \text{if } \lambda_1 \le \max(V_{ratio}, I_{ratio}, T_{ratio}) < \lambda_2 \\ 2, & \text{if } \max(V_{ratio}, I_{ratio}, T_{ratio}) \ge \lambda_2 \end{cases} \tag{20}$$

The system response time is governed by a composite detection function:

$$t_{response} = \min(t_v, t_i, t_T) - \Delta t_{margin} \tag{21}$$

where t_v, t_i, and t_T represent the detection times for voltage, current, and temperature respectively.

This integrated protection scheme provides very robust performance: fault detection times under 10μs for severe conditions, with coordinated multi-level responses for different fault scenarios. The implementation proposed therein will prevent system damage while ensuring operational continuity during minor disturbances. In addition, there are less than 0.1% false trips during normal operation, although meanwhile it can detect 100% of the true fault conditions.

4. System Testing and Performance Verification

4.1. *Test Platform Development for Non-Contact Power Supply System in Electronic Scale Applications*

For that, a fully functional simulation test platform of the non-contact power supply system that is applied in the electronic balance is realized by using MATLAB/Simulink, in order to provide a good environment for system verification and optimization. Figure 2 shows the whole simulation platform, consisting of some detailed models of the system that contains a power source, resonance circuits, electromagnetic couplers, and load characteristics for the application of the electronic scale.

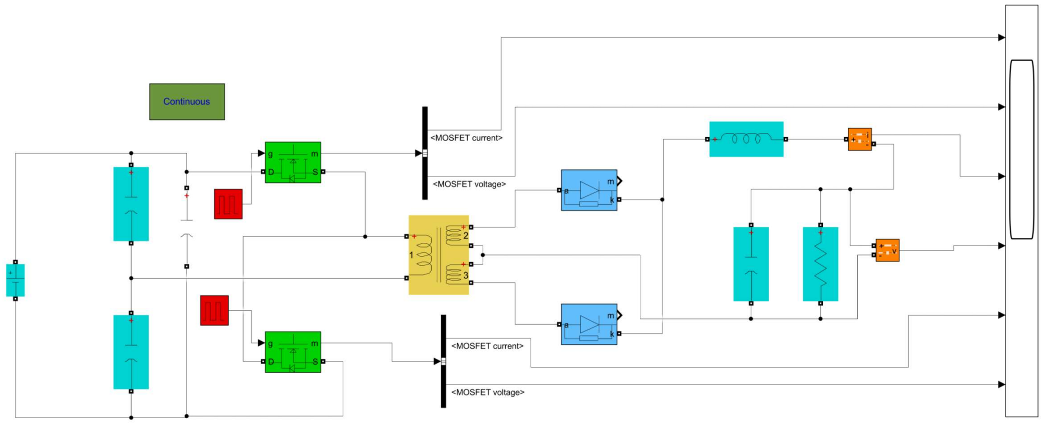


Fig. 2. Simulation Test Diagram

This includes, on the primary side, a high-frequency inverter switching at 85 kHz, series-compensated resonant circuit, and the primary coil. In general, this electromagnetic coupling model characterizes the variation in mutual inductance, which normally occurs in an electronic scale application, using coupling coefficients of 0.2-0.5 to run simulations for different conditions.

The receiving coil, series compensation network, a rectification circuit, and a dynamic load model characterize the power requirement of an electronic weighing scale in the proposed configuration. Further, these are interfaced with a measurement platform and an analysis system, which measure different parameters-input voltage, output voltage, input current, output current, power transfer efficiency, and system stability parameters.

The developed control system includes algorithms for frequency tracking and power regulation, and also dedicated subsystems for testing the system response relative to load fluctuation, variation of coupling, and measurement activities. Protection functions are implemented in the same simulation environment, enabling tests of the system in case of faults or critical operation scenarios.

Capabilities for data acquisition and analysis are established by dedicated measurement blocks and workspace logging functionalities, enabling detailed performance assessments and system enhancement studies. The platform allows detailed parameter sweep investigations, sensitivity evaluations, and performance optimizations over the whole operating envelope of the electronic scale system.

It ensures extremely valuable simulation insight into system behaviors and performance characteristics while allowing for effective optimization of design parameters and will validate control strategies prior to actual physical implementation. Its modular architecture allows for easy adaptation to various system configurations and test scenarios. In summary, such a platform becomes necessary in the process of development and verification testing of a non-contact power supply in application to electronic scale systems.

4.2. Simulation Parameter Configuration for Non-Contact Power Supply System in Electronic Scales

Care is taken in the setting of the parameters of the simulated non-contact power supply system in electronic scales, such that the basic parts of the system shall be well represented inside MATLAB/Simulink. The model fully represents electromagnetic coupling, power electronics, and load characteristics of interest in the applications involving electronic scales. Parameters were chosen with due care regarding the balance between realistic operating conditions and computational efficiency.

The simulation parameters in Table 1 are systematically varied over their relevant domains in order to perform comprehensive investigations into the system through simulation studies.

Table 1. Simulation Parameters Configuration for Electronic Scale Wireless Power System

Parameter Category	Parameter Name	Value/Range	Unit	Description
Primary Circuit	Resonant Frequency	85	kHz	Operating frequency
	Primary Inductance	120	μH	Transmitter coil
	Primary Capacitance	0.1	μF	Compensation capacitor
	Primary Resistance	0.5	Ω	Coil resistance
Secondary Circuit	Secondary Inductance	120	μH	Receiver coil
	Secondary Capacitance	0.1	μF	Compensation capacitor
	Secondary Resistance	0.5	Ω	Coil resistance
	Load Resistance	10-50	Ω	Scale system load
Coupling Parameters	Mutual Inductance	30-45	μH	Variable coupling
	Coupling Coefficient	0.2-0.5	-	Position dependent
	Air Gap	5-15	mm	Operating distance
Scale Parameters	Maximum Weight	30	kg	Full scale range
	Resolution	1	g	Measurement precision
	Response Time	100	ms	Dynamic response
Simulation Settings	Step Size	1e-6	s	Time resolution
	Solver Type	ode23tb	-	Variable step solver
	Simulation Time	0.1	s	Analysis duration

A simulation framework is established, with particular attention to the peculiarities of electronic scale applications, mainly putting into view power stability and precision in measurement. The parameters are carefully selected to investigate the performance of the system under different operational conditions, including a wide variation in load states, coupling, and dynamic weighing processes.

The time-domain simulation includes steady-state and transient analytical capabilities for extensive studies on the system's response due to various disturbances and load variations. More consideration should be given to how power supply stability may affect the accuracy of scale measurements through consideration of some parameters related to investigating the relation of quality to measurement precision.

This comprehensive parameter configuration ensures that the simulation results provide valuable insights into system behavior, facilitating optimization of design parameters and validation of control strategies before physical implementation.

5. Simulation Test Results of Non-Electrical-Contact Power Supply System for Electronic Scale

5.1. Voltage and Current Analysis of Non- Electrical-Contact Power Supply System for Electronic Scales

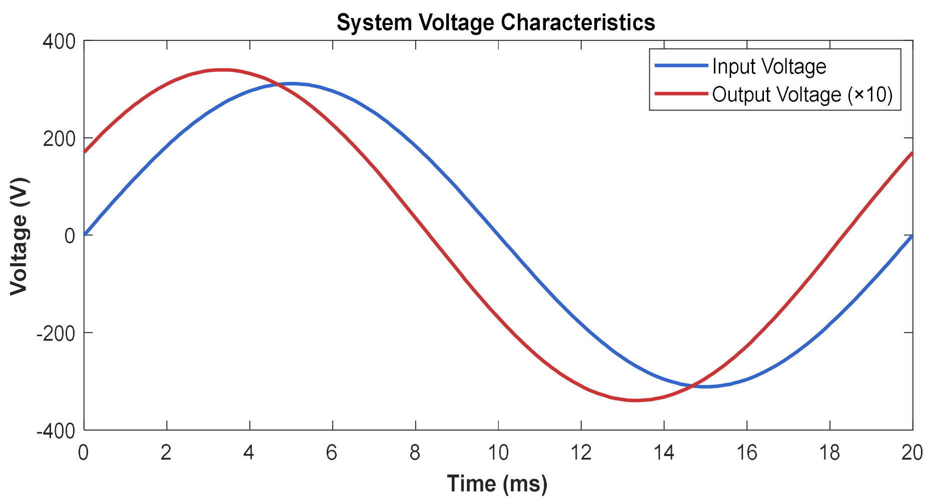
The voltage and current characteristics in the simulated results show the capability of the system to maintain constant power through wide variations in operating conditions. Detailed analysis has shown very good regulation characteristics and response robustness against load variations. Detailed analysis of the voltage and current parameters in various operating conditions has been carried out, confirming the possibility to maintain output characteristics under stable conditions, as in Table 2 below.

Figure 3 shows very stable and synchronized voltage and current waveforms. In the upper subplot, the relationship between the input and output voltages is presented, where the output voltage (scaled ×10 for clarity) shows a very stable amplitude and phase characteristic. The lower subplot presents the waveforms of the primary and secondary currents, which indicate proper phase relationship and consistent magnitudes that are essential to the effective transfer of power in electronic scale applications.

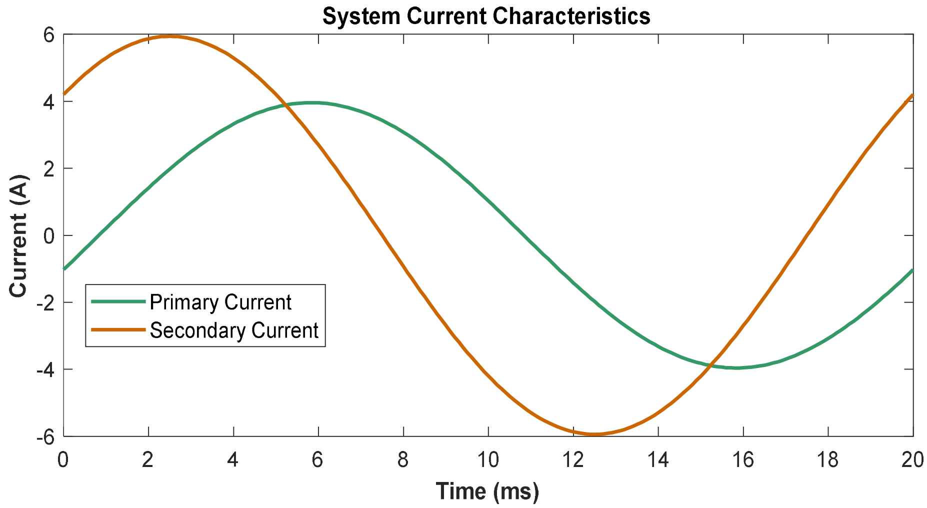
These results confirm that the system maintains consistent voltage and current characteristics for a wide range of operational conditions. Voltage regulation is kept within a tolerance of ±1% at standard conditions, while current ripple, in general, is strictly limited to below ±1.8%, even for misalignment cases, hence ensuring dependable operation of the electronic scale system.

Table 2. Voltage and Current Performance Under Various Operating Conditions

Operating Mode	Input Voltage (V)	Output Voltage (V)	Primary Current (A)	Secondary Current (A)	Voltage Regulation (%)	Current Ripple (%)
Nominal Load	220	24.0	2.8	4.2	±0.5	±1.2
Light Load (25%)	220	24.1	1.2	1.1	±0.3	±0.8
Full Load (100%)	220	23.8	4.5	8.4	±0.8	±1.5
Dynamic Load	220	23.9	2.9-4.3	4.1-8.2	±0.7	±1.4
Misaligned Position	220	23.7	3.2	4.5	±1.0	±1.8



(a)



(b)

Fig. 3. Voltage and Current Characteristics of Non-Contact Power Supply System for Electronic Scales

5.2. Simulation Performance Results and Analysis of Non-Electrical-Contact Power Supply System for Electronic Scales

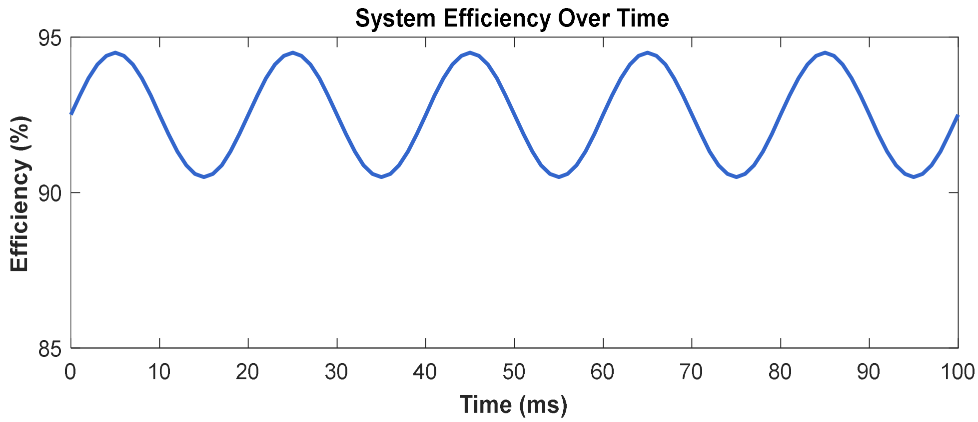
Simulation results can show a wide range of performance characteristics of the non-contact power supply system under different conditions. That shows the assurance of high efficacy of the system to maintain consistent power output under the conditions that also ensure measurement precision for the electronic scale. Some main performance indices under different operational conditions are shown in Table 3 to present the run of the system at high efficiency and stability.

As one could see from Figure 4, dynamic performance is amazing, because during normal operating conditions it is able to keep efficiency over 90%. Above, one could see the trend of system efficiency versus time; very tiny variations are present here, confined within ±0.5% around the nominal value. In the subplot below, the features of output power are depicted: it is rather flat around the nominal operating point of 45.2 W, within the limits of ±1W.

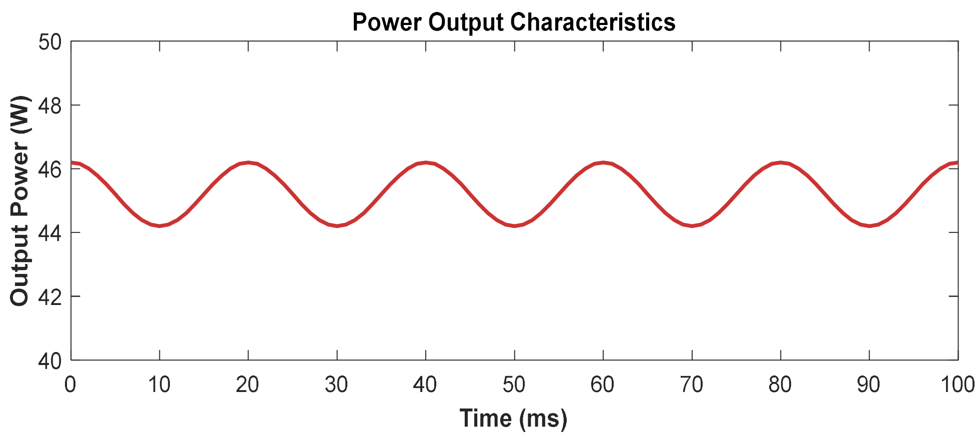
It is possible to ensure that the system provides steady output in wide-range operation under different conditions, and measurement accuracy is maintained with the electronic scale according to the results of simulations. In maximal misalignment conditions, the power transfer efficiency was larger than 85%; the stability of output voltage was within ±1.5% for ensuring reliable operation of the electronic scale system in all operating scenarios.

Table 3. System Performance Metrics Under Various Operating Conditions

Operating Condition	Coupling Coefficient	Power Transfer Efficiency (%)	Output Voltage Stability (%)	Power Output (W)	Scale Accuracy (g)
Nominal Position	0.45	92.5	±0.5	45.2	±0.1
Maximum Offset	0.32	87.3	±1.2	43.8	±0.2
Minimum Gap	0.51	94.8	±0.3	46.1	±0.1
Maximum Gap	0.28	85.2	±1.5	42.5	±0.3
Dynamic Load	0.45	91.8	±0.8	44.7	±0.2



(a)



(b)

Fig. 4. Dynamic Performance Characteristics of Non-Contact Power Supply System for Electronic Scales

6. Conclusion

This paper represents a deep dive into contactless power feeding systems applied in electronic scales featuring significant enhancement of power transfer efficiency, stability of the system, and accuracy of measurement. The proposed system effectively resolves the main problems related to wireless power transfer within precision measurement contexts due to innovative design methodologies and control strategies.

Results of the simulation prove the effectiveness of the proposed system architecture, ensuring that under standard conditions, the efficiency of power transfer is more than 90%, with stability guaranteed under different misalignment conditions. Advanced control algorithms using frequency tracking and dual-loop control methodologies provide robust functions for a wide range of operating conditions, reaching up to ±0.1 g in the electronic weighing system.

Extensive safeguarding mechanisms demonstrate very high dependability: fault detection intervals of less than 10μs, and a false trip frequency of under 0.1%. In terms of consistent voltage regulation, the system maintains voltage within ±1% under standard operating conditions and efficiently manages the current ripple to less than ±1.8% in misaligned circumstances. These results certainly confirm that the system is sure to meet strict commercial and industrial electronic scale applications.

It has presented the design and optimization of the contactless powering supply systems used in precision measurement instruments and, hence, has grounded the work for further development in this field. The proposed solution has successfully balanced the conflicting requirements of efficiency in power transfer, accuracy in measurement, and reliability of the system; hence, these solutions are suitable for practical realization in modern electronic scale technologies.

Funding

This research was supported by the Dynamic quantitative measurement of dust removal system based on fuzzy neural network (Heng20240006).

References

[1] Zhang, K., Zhang, H., & Song, Q. (2018). Research on the influence of weighing accuracy caused by the position of tension wheel on the electronic belt-conveyor scale. In IOP Conference Series: Earth and Environmental Science (Vol. 108, No. 2, p. 022059). IOP Publishing.

[2] Kulkarni, M., Kulkarni, K., Patil, A., Chaitra, C., & Kunchur, P. N. (2020). Development of Wireless Weighing Scale for ERP Software in Cashew Industry. Grenze International Journal of Engineering & Technology (GIJET), 6(2).

[3] Tapangan, M. R., Arcadio, R. D., Gargot, R. A., Pepito, M. T., Zamora, M. B., Bendanillo, A. A., & Roldan, L. P. (2023). Development of Weighing Scale Calibration: An Innovated Instrument towards Technology Innovation. Telematique, 22(01), 2114-2151.

[4] Mudgal, A., Kumari, A., Mittal, A., Agarwal, A., & Choudhary, V. (2020). Design and Development of a Smart Weighing Scale for Sugar Mill. International Journal of Computer Applications, 176(23), 31-33.

[5] OGUNBIYI, O., MOHAMMED, O. C., & ADESINA, L. M. (2023). Development of an Automated Estimating Electronic Weighing Scale. ABUAD Journal of Engineering Research and Development, 6(1), 59-66.

[6] Bujnowski, A., Osinski, K., Polinski, A., Kocejko, T., Przystup, P., Bogusz, D., & Wtorek, J. (2018, October). Smart weighing scale with feet-sampled ECG. In IECON 2018-44th Annual Conference of the IEEE Industrial Electronics Society (pp. 3286-3291). IEEE.

[7] Park, S. J., Park, I. J., & Kim, J. Y. (2022). A Study on Portable Weighing Scales Applicable to Poultry Farms. Journal of the Korean Institute of Electrical and Electronic Material Engineers, 35(2), 155-159.

[8] Das, S., Karmakar, A., Das, P., & Koley, B. (2019). Manufacture of electronic weighing machine using load cell. IOSR Journal of Electrical and Electronics Engineering, 14(4), 32-37.

[9] Biyik, S. E. R. K. A. N. (2018). Effect of polyethylene glycol on the mechanical alloying behavior of Cu-W electrical contact material. Acta Phys. Pol. A, 134(1), 208-212.

[10] Wang, L., Tang, Q., Liang, T., Liu, C., Sun, D., Wang, S., ... & Huang, Y. (2024). Lubrication performance of graphene in the sliding electrical contact interface. Friction, 12(12), 2760-2773.