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Comparative Analysis of Power Supply Devices Using Gray Relational Analysis: Optimizing Efficiency and Environmental Impact

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Abstract: This study employs Gray Relational Analysis (GRA) to evaluate and compare various power supply devices, including switched-mode power supplies, linear power supplies, uninterruptible power supplies, battery packs, and solar power systems. The analysis focuses on four critical parameters: power requirements, efficiency, environmental factors, and noise sensitivity. The research methodology involves normalizing data, calculating deviation sequences, and determining Gray Relation Coefficients for each device across the four parameters. The final step computes the Gray Relation Grade (GRG) to rank the power supply options. Results indicate that battery packs emerge as the top-ranked power supply device with a GRG of 0.8333, excelling in power requirements, efficiency, and environmental factors. Solar power systems secure the second position with a GRG of 0.5525, demonstrating a balanced performance across all criteria. Linear power supplies, switched-mode power supplies, and uninterruptible power supplies follow in descending order. The study highlights the importance of considering multiple factors in selecting power supply devices for various applications. While battery packs show overall superiority, each type of power supply exhibits unique strengths suitable for specific use cases. The analysis underscores the need for a holistic approach in power supply selection, taking into account not only efficiency but also environmental impact, noise sensitivity, and power requirements. The strong performance of battery packs and solar power systems indicates a trend towards more sustainable and flexible power solutions. Future developments may focus on improving the efficiency and environmental impact of these leading options while addressing the specific strengths of other power supply types to create more versatile and optimized power solutions.

Keywords: Power Supply Devices, Efficiency, Environmental Factors, Noise Sensitivity, Battery Packs, Solar Power Systems, Switched-mode Power Supplies, Uninterruptible Power Supplies and Sustainable Energy Solutions.

1. INTRODUCTION

High voltage results in low power supply and the optimum method to achieve this can be determined using a fly back converter. This approach simplifies the design, making the device smaller, easier to fabricate, and more cost-effective. In this paper, the circuit of the device is simulated using PSPICE software to analyze its output characteristics and voltage. Focus is on design, simulation and construction of fly back converter. The principles behind the fly back converter are examined to determine the most suitable design. Selected circuit components are simulated and their values are calculated. Finally, the device circuit is tested, and the output variables are compared with the simulation results [1]. Recent advances in materials, fabrication techniques, and device systems have led to the development of unique electronics using biomaterials. These devices are designed to closely mimic soft, curved tissue and have the ability to interact with transient properties. They have significant potential to improve human health. Furthermore, these devices continue to aid biomedical research, including wireless soft miniaturized optoelectronic systems in opt genetics and bioresorbable electronic stents integrated with nano particles for the treatment of endovascular diseases. Despite considerable progress in the development of small, flexible and bio-absorbable implantable bioelectronics, especially in meeting clinical standards, the need for autonomous power

solutions remains a challenge. Overcoming barriers in remote sensing, communication, and continuous therapies is critical to further advancement of these technologies [2]. Unlike traditional fabrication methods, printing technologies show great promise. The use of nano materials, with their unique properties, is a reliable strategy to improve the performance of these devices. This review provides an overview of the development of printable techniques that could revolutionize the fabrication of integrated systems in an attractive format. It first summarizes the advantages and limitations of commonly accepted printing techniques for fabricating power supply devices. Subsequently, it explores research progress on printable energy harvesting and conversion devices such as solar cells, nano generators, and innovative bio fuel cells. The possibilities of printed energy storage devices including super capacitors and rechargeable batteries are also discussed separately [3]. Pacemakers, monitoring devices, functional electronics, left ventricular assist devices, and various artificial hearts have found widespread use in biomedical applications. One of the major challenges is ensuring a reliable power supply for the long-term operation of these medical devices. Traditionally, implantable batteries and percutaneous connections have been used to provide power. However, batteries have low energy storage and long life, while percutaneous connections pose a significant risk of infection. To address these issues, wireless power supply systems for implantable biomedical devices have been developed, allowing power transfer over relatively large air gaps [4]. In practice, RF power quality is highly sensitive to the position of the receiver antenna in the RF electromagnetic field. Therefore, the on-chip energy storage component plays an important role in providing localized power for continuous and reliable operations such as wireless data transmission. To ensure efficient operation while providing sufficient power, it is essential to develop compact energy-saving solutions that meet clinical size constraints and maintain a small form factor. Unfortunately, research on integrating miniature energy-storage components directly into chips remains scarce and underdeveloped [5]. This noise reduces the actual voltage level reaching the device, leading to propagation delays in both cells and interconnects. As a result, signal arrival times at primary outputs are delayed, affecting subsequent state transitions. If the affected cell is a clock buffer or part of a time-critical path, this delay variation can cause severe clock skew problems or a small increase in critical path delay. Therefore, timing analysis for deep submicron devices must account for this effect. Power supply noise is affected by the input pattern, meaning that different input patterns produce different noise levels, leading to different cell or inter-cell delay variations. Additionally, because voltage levels and delay times are closely related, accurate propagation delay calculations for cells and interconnects cannot be made until the associated power supply noise is evaluated [6]. It is clear that using wide band gap (WBG) devices instead of silicon can enhance the performance of any design. However, focusing solely on this benefit would underestimate the full potential of WBG technology. WBG devices can also operate at higher frequencies compared to their silicon counterparts. This allows for a size and weight reduction of 5-10 times in certain applications, with some already proven in practice. Despite these advantages, fully replacing silicon with WBG doesn't yet seem feasible. For instance, while a converter with WBG devices can achieve a 10X improvement, silicon devices operating at 20X or 50X the switching frequency could still challenge the design in current practice [7]. Capacitance in a single-phase circuit is not only affected by the phase structure but also by factors such as temperature, icing on the line and handling during networking. These variations can also be caused by frequency fluctuations and other factors. Therefore, the arc suppression coil must be constantly maintained at a value that resonates with the potential of the induction phase. To achieve this, the coil is divided into two parts: an adjustable load bearing element and a control unit. The control unit affects the load-bearing element, allowing the inductance of the coil to be instantly adjusted in response to changes in the overall potential of the power grid [8]. Among modern industrial enterprises in various regions, the primary trend in designing electricity distribution systems involves the use of distributed local generation and integrated use of renewable resources. Ensuring the continuity and stability of technological processes within industrial enterprises is important, especially for major power consumers. For example, in oil production companies, these consumers include centrifugal pumps and submersible motors for pipelines, while in cable manufacturing companies, such consumers include the installation of cross-linked polymer insulation in cables. According to theoretical and experimental studies for such installations, permissible voltage drops and power supply interruptions should not exceed 0.15 seconds [9]. It is easy to understand that during a power outage in a hospital, if a medical electrical device does not have an internal battery, it will stop working. However, when a voltage drop occurs, it can lead to malfunction or failure of some devices, although not all of them are affected. Interestingly, even lighting systems may not experience problems during a power supply problem. As a result, the reasons why medical electrical equipment shuts down during voltage drops are often unclear. Nevertheless, reports indicate that malfunctions and malfunctions of medical electrical devices occur in the electromagnetic environment [10]. We define communication in terms of electricity by introducing Cyber-Physical Systems (CPS) for electronic devices that include electricity measurement, computation and communication. Additionally, we illustrate example applications that can be implemented within

this framework. We propose integrating AC to DC power supplies as a basic component of every electronic device. This power is converted by a transformer whose voltage and current ratios range from 1 to 100 depending on the input voltage and power requirements. Measuring these variables is cost-effective, enabling efficient manipulation of electrical parameters. The proposed variable-speed systems represent an advanced and efficient technology that makes companies viable candidates for using variable power supplies. This approach, characterized by low costs and seamless integration with existing technology, supports energy awareness in various device types and facilitates the adoption of IoT concepts [11]. The research described here aims to maximize the power transferred from a vibrating piezoelectric transducer to a battery through an innovative approach. The paper begins by presenting a simple model of a piezoelectric transducer. An AC-DC rectifier is incorporated in this model to identify the optimum power flow point for the transducer. To achieve this optimal power flow, the paper introduces an adaptive switch-mode DC-DC converter. This adaptive approach works similarly to the maximum energy point monitoring systems used to harness energy from solar cells [12]. The idea of monitoring and regulation is rooted in the Internet of Things (IoT). To achieve this, computers are integrated with wireless sensor nodes (WSNs) to form Microsystems. However, these sensors often require significant amounts of electricity, leading to an over-reliance on batteries, a major challenge. The main issue is that batteries have a short lifespan, need to be replaced or recharged, and introduce harmful pollutants into the environment. To mitigate excessive pollution and ensure energy independence, wireless sensors should use energy-harvesting techniques from their surroundings or rely on wireless power transfer solutions, a highly recommended approach that eliminates the need for battery replacement [13]. Unregulated access to education is a significant barrier to progress in developing countries, particularly in rural areas. Lack of reliable electricity affects the teaching of science, engineering and basic technology experiments. Electricity plays an important role in national development, enabling individuals to improve their domestic conditions and facilitating various forms of production, from cottage industries to small and medium enterprises. In laboratories, a laboratory bench power supply is a fixed electrical/electronic unit that supplies the required power. However, these units rely on an unstable power supply, and frequent power outages render them useless. As a result, alternating current (AC) or direct current (DC) is the essential voltage requirements for basic laboratory testing that are often compromised or interrupted [14]. With more surveillance equipment, problems with power supply are increasing. Common methods of operating monitoring devices include wired connections and battery operation. When devices are installed in dense configurations, a wired power supply requires complex circuitry and requires considerable manpower and resources. Additionally, damaged electrical wires can lead to short circuits, posing a greater risk of fire or other accidents. On the other hand, battery-powered systems require regular checks, including battery replacement, as battery capacity and maintenance decrease. Also, heavy metals in damaged batteries can harm the environment [15].

2. MATERIALS AND METHOD

Switched-mode power supplies: A switch-mode power supply, also referred to as a switching power supply or simply a switcher, is an efficient electronic power supply that uses a switching regulator to convert electrical power.

Linear power supplies: A linear regulator is a type of voltage regulator integrated circuit (IC) designed to maintain constant output voltage regulation in response to variations in input voltage or output current, acting like a resistor. There are two main types of linear regulators: series regulators and shunt regulators. Linear power supplies, often referred to as series power supplies, operate at low frequencies and do not use any switching elements during regulation. Because of their low operating frequency, transformers used in these supplies are bulky compared to transformers found in switch-mode power supplies.

Uninterruptible power supplies: An uninterruptible power supply is a device that keeps a computer running at least briefly during a power outage. It provides power by replenishing and maintaining energy reserves, protecting devices from damage in the event of a UPS power failure.

Battery packs: A battery pack consists of identical batteries or individual battery cells. These packages can be configured in series, parallel or a combination of both to provide the desired voltage and current. From computers and cell phones to personal grooming devices, battery-powered electronics have become integral to modern society. Without batteries we would be at a loss. The three main types of batteries commonly used by consumers are alkaline, nickel-metal hydride (NiMH), and lithium-ion.

Solar power systems: Solar power harnesses energy from the sun and converts it into usable forms. There are two main types of energy produced from solar energy: electricity and heat. Both are generated using solar panels that can be found on residential rooftops or in extensive solar farms spread over large areas of rural land.

Power requirements: Watts (W) are the basic units used to measure electricity, heat and mechanical power. A watt equals one joule and one volt-ampere, and these terms are primarily used to measure electrical power. In residential and commercial settings, electricity is often measured in kilowatts. The stability of the voltage, including its magnitude and load angle, is important in the transmission system, which includes various components: generation units, transformer units, converter units, transmission units, inverter units and consumer points. Collectively, these components are known as the overall power system.

Efficiency: Errors or deficiencies in work performance led to waste of energy, effort, money and time. Avoiding such inefficiencies is often considered a measurable skill. In broad terms, it refers to the ability to perform tasks efficiently, effectively and without unnecessary waste.

Environmental factors: Environmental factors such as water quality, air quality, and weather often vary by location and population. Although many environmental conditions are naturally occurring, the overall quality of the environment and its impacts are significantly influenced by historical, economic and socio-political factors.

Noise sensitivity: Hyperacusis is a hearing disorder that causes difficulty in tolerating everyday sounds. It may also be referred to as sound or noise sensitivity. Individuals with hyperacusis may perceive certain sounds as too loud, even if those around them do not notice any problems.

3. GRA METHOD

The GRA model proposed by Deng Zhulong has been the focus of extensive research by many scholars, which has led to meaningful advances in the construction of GRA models that emphasize various properties and provide valuable results. The research process has evolved from early GRA models, which were primarily based on correlation coefficients, to more general models. Integrative or cumulative overview perspectives and GRA models represent an integrated approach and are closely linked to proximity assessment models, which essentially measure similarity. Furthermore, the scope of the research includes the analysis of relationships involving surfaces, not only between curved surfaces, but also in three-dimensional and n-dimensional spaces [16]. Criterion values are often expressed as linguistic variables by objective factors, represented as interval-valued triangular fuzzy numbers. The primary objective of this paper is to develop an extended gray correlation analysis (GRA) method for solving multi-criteria decision-making (MCTM) problems. To determine the criterion weights, the traditional GRA method is improved with some optimization models based on its basic principles. Then, the computational steps of the extended GRA method for MCDM are outlined. Finally, the effectiveness and feasibility of the developed method is verified through a numerical example [17]. Intuition related to incomplete weight information poses challenges to traditional GRA methods when dealing with fuzzy multi-attribute decision making (MADM) problems. The basic concept of the traditional GRA method revolves around the determination of attribute weights, but both fuzzy intuition and incompletely known attribute weight information provide intriguing and significant research topics. Therefore, to solve MADM problems involving fuzzy information, this paper extends the GRA concept to develop a method involving incompletely known attribute weight information, where the attribute values are represented as intuitive fuzzy numbers. Motivated by this discussion, the paper proposes an extension of the GRA method to an interval-valued Pythagorean fuzzy context, using Coquet integration instead of extending it within the conventional framework [18]. Electrically conductive materials with low mechanical strength are best suited for forming complex shaped profiles. Because there is no direct contact between the tool and the work piece, this process reduces mechanical stress build-up, chatter, burr formation and vibration problems. Machining performance is unaffected by the hardness of the work material, as high local heat generation leads to melting and facilitates material removal. Because this process does not involve cutting force, it allows a high ratio of minimal tools to efficiently machine very deep, narrow holes. Additionally, complex cavities can be created during machining. However, this process has several drawbacks, including the formation of a reactive layer, low material removal rates, high machining costs, extended machining time, and limited flexibility due to reliance on electrical conductivity to process only certain materials [19]. In an increasingly competitive environment with rising pressures, ensuring the success of hospitals in future growth heavily relies on providing high-quality medical services. Employees are becoming more aware that the quality of medical services is a critical factor. If patients are dissatisfied with the services offered by a hospital, they will likely seek treatment elsewhere. Therefore, hospitals that focus on enhancing the quality of their services and overall efficiency will be better positioned to retain existing patients and attract new ones [20]. To improve the experience for mobile users, various multi-attribute decision making (MADM) methods have been used for network selection purposes. These MADM algorithms assist in decision making by evaluating alternatives based on multiple influential criteria and determining their rankings according to user preferences. The primary goals of these

solutions include reducing frequent handover processes and ensuring acceptable quality of service (QoS) characteristics to support a wide range of applications. A network selection algorithm automatically identifies accessible networks based on requested services and evaluates performance factors such as latency, jitter, cost, and signal strength, thereby providing the best interface tailored to user needs [21]. The multi-objective optimization of the elastic member of the transducer focuses on reducing strain through size reduction while ensuring the gauge can withstand maximum pressure. The Finite Element Method (FEM) software is employed for optimal design. An integrated approach that combines Taguchi methods and Gray Relational Analysis is used for optimization. An orthogonal array is created based on the parameters selected in the Taguchi method. Following this, multi-objective optimization is carried out using the Taguchi method, which incorporates both Taguchi and Gray relational analysis. This combined approach aims to maximize gray correlation, providing an optimal parameter combination based on coefficients. Additionally, analysis of variance is utilized as a statistical technique to evaluate the performance characteristics of each process parameter [22]. Real numbers, evaluative information from decision makers, interval-valued numbers, linguistic variables, and intuition are represented as fuzzy numbers. This intuitively ambiguous evaluation information can be converted into numerical form. An integrated GRA approach to group decision making is proposed to address this ambiguity. First, the hybrid result matrix is standardized, followed by intuitively transforming the fuzzy results into a group form. Next, an intuitive fuzzy averaging operator is used to aggregate the decision makers' ideas. Entropy is used to obtain scale weights that reflect the ambiguity of intuition. After computing the best solutions for both intuitively ambiguous positive and negative scenarios, gray correlation coefficients for the alternatives are obtained and ranked accordingly. Finally, a numerical example is presented to demonstrate the validity and applicability of the proposed method [23]. This network consists of various types of terminals and devices configured in many ways, all of which are accessible through advanced technologies. This integration aims to improve performance while providing flexibility to users. As a result, managing transitions between different wireless networks has become a common solution in today's wireless systems. Handover processes are primarily divided into two categories: horizontal handover and vertical handover. Horizontal handover occurs when a mobile terminal moves between access points using the same wireless technology. In contrast, vertical handover refers to the delegation process that occurs when a mobile terminal switches between access points using different wireless technologies [24]. Wire EDM (WEDM) is a highly adaptable non-traditional machining process capable of cutting extremely hard materials and creating intricate and complex shapes in a wide variety of materials. Material hardness does not pose a limitation to WEDM, making it easy to cut challenging materials. Key parameters affecting material removal include material removal rate (MRR), surface area and factors such as pulse time, pulse duration, discharge current, servo voltage, wire tension and flushing pressure. Hence, it is important to optimize these parameters to achieve maximum output. Using Taguchi and Gray correlation analysis methods, research was conducted to determine the optimal settings for achieving the highest MRR and shortest kerf (width of cut) for Hostelry C276, a nickel-based alloy known for its high temperature and corrosion-resistant properties [25]. Achieving optimal joining of materials without defects is critical and depends on specific engineering process parameters at key steps in the engineering process. Fusion welding is commonly used in standard joining procedures. However, this method often experiences significant pitting due to temperature gradients, resulting in excessive heat and stress during rapid solidification, which can lead to segregation. As natural resources become increasingly scarce, innovative fusion practices are being developed to address the negative effects associated with traditional fusion methods [26]. To meet the growing demands of logistics, companies operating in dynamic environments must rely on ERP vendors to continuously provide or develop new business solutions. As a result, companies must carefully select ERP software packages from the wide variety of options available in the market. Since inappropriate choices lead to failures, choosing the right ERP package is a strategic decision that significantly affects the company's performance during the implementation phase. In this paper, gray correlation analysis (GRA) is used to address the intuitive ambiguity associated with the software selection process for ERP systems. Initially, we determine the weights using the IFS method, and then the alternatives are selected by ranking and GRA [27]. Multi-criteria decision-making methods are useful tools for selecting optimal output characteristics. In these methods, various criteria are analyzed to select the best alternative from the available options. Various MCDM approaches, including Taguchi orthogonal designs, are used in engineering problems for material selection and process optimization. The GRA method is used in the context of hydro optimization in the MCDM process. The study investigated abrasives in water jet cutting using a multi-response optimization GRA method, revealing that multiple response characteristics can be optimized through this cutting process. Consequently, microcellular polymeric nano composites emerge as excellent candidates for injection molding based on the analysis of mechanical and morphological properties [28]. Many business challenges stem from an ineffective motivational system. Issues such as decreased employee engagement, subpar performance during the recruitment process,

inefficient practices, poor interpersonal relationships, and high turnover rates contribute to ineffective collaboration across various sectors. This lack of control over manpower results from these underlying issues. Furthermore, these conditions often arise from a failure to adhere to fundamental business ethics and the inadequate implementation of motivational strategies [29]. In a hesitant fuzzy environment, multiple attributions can address the uncertainty of information in portfolio selection, an area where traditional methods fall short. This study employs Hesitant Fuzzy Elements (HFE) to integrate specified attribute values using Gray Relational Analysis (GRA), thereby providing a framework for uncertain information. As a result, the process of portfolio selection becomes more intricate within a firm’s information environment [30].

4. ANALYSIS AND DISCUSSION

TABLE 1. Power supply device

	Power requirements	Efficiency	Environmental factors	Noise sensitivity
Switched-mode power supplies	102.13	145.11	81.61	10.20
Linear power supplies	104.25	189.47	51.41	70.77
Uninterruptible power supplies	106.81	143.69	91.87	50.96
Battery packs	109.23	196.54	11.51	90.99
Solar power systems	107.56	171.25	61.74	40.11

Table 1 compares various power supply devices using the GRA method, highlighting key metrics such as power requirements, efficiency, environmental factors, and noise sensitivity. Switch-mode power supplies require 102.13 units of power with 81.61 efficiency and low noise sensitivity (10.20). Linear power supplies, with slightly higher power requirements (104.25), offer higher efficiency (51.41), but have higher noise sensitivity (70.77). The uninterruptible power supply has a power requirement of 106.81, high efficiency (91.87) and moderate noise sensitivity (50.96). Battery packs claim high power (109.23) with low efficiency (11.51) and high noise sensitivity (90.99), while solar power systems balance moderate power requirements (107.56) and decent efficiency (61.74) with low noise sensitivity (40.11).

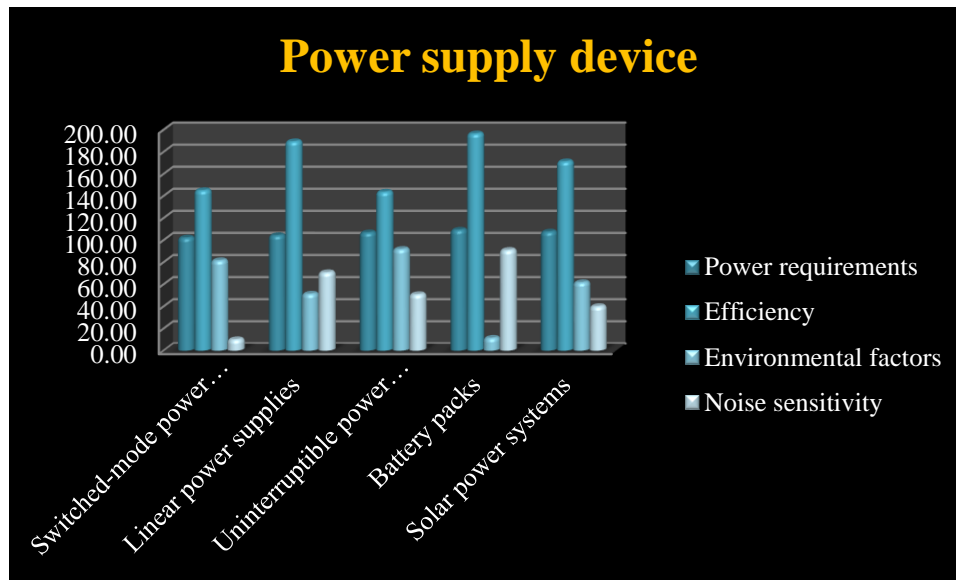


FIGURE 1. Power supply device

Figure 1 illustrates the evaluation of various power supply devices using the GRA method. Switch-mode power supplies exhibit lower power requirements (102.13) and noise sensitivity (10.20), while linear supplies require more power (104.25) but have higher noise sensitivity (70.77). Uninterruptible power supplies show good performance (91.87), and battery packs demand more power (109.23) with less performance (11.51). Solar power systems offer balanced performance with moderate power requirements (107.56) and decent efficiency (61.74).

TABLE 2. Normalized Data

	Power requirements	Efficiency	Environmental factors	Noise sensitivity
Switched-mode power supplies	0.0000	0.0269	0.1277	1.0000
Linear power supplies	0.2986	0.8662	0.5035	0.2503
Uninterruptible power supplies	0.6592	0.0000	0.0000	0.4955
Battery packs	1.0000	1.0000	1.0000	0.0000
Solar power systems	0.7648	0.5215	0.3749	0.6298

Table 2 presents the normalized data for various power supply devices using the GRA method, reflecting their performance across key parameters. Switched-mode power supplies scored lowest in power requirements (0.0000) but showed a significant noise sensitivity rating of 1.0000, making them suitable for noise-sensitive applications. Linear power supplies demonstrated balanced efficiency (0.8662) and moderate environmental factors (0.5035), with lower noise sensitivity (0.2503). Uninterruptible power supplies achieved the highest score for power requirements (0.6592) but had zero efficiency, indicating limited use. Battery packs received perfect scores across power, efficiency, and environmental factors, yet had no noise sensitivity (0.0000). Solar power systems showed a good compromise, with scores of 0.7648 for power requirements and 0.5215 for efficiency, alongside moderate noise sensitivity (0.6298).

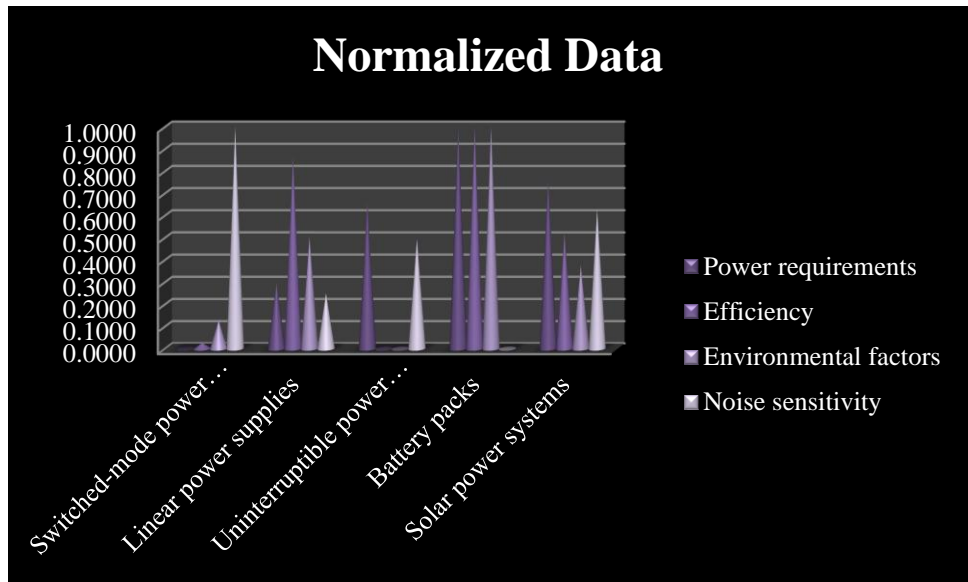


FIGURE 2. Normalized data

Figure 2 shows the normalized data for various power supply devices evaluated using the GRA method. Switch-mode power supplies have very low power requirements (0.0000) but high noise sensitivity (1.0000). Battery packs score perfect across energy, efficiency and environmental factors, while uninterruptible power supplies rank high in power requirements (0.6592) but zero in performance. Linear power supplies show good efficiency (0.8662) and moderate environmental factors (0.5035), and solar power systems strike a balance with scores of 0.7648 in power requirements and 0.5215 in efficiency.

TABLE 3. Deviation sequence

	Power requirements	Efficiency	Environmental factors	Noise sensitivity
Switched-mode power supplies	1.0000	0.9731	0.8723	0.0000
Linear power supplies	0.7014	0.1338	0.4965	0.7497
Uninterruptible power supplies	0.3408	1.0000	1.0000	0.5045
Battery packs	0.0000	0.0000	0.0000	1.0000
Solar power systems	0.2352	0.4785	0.6251	0.3702

Table 3 outlines the deviation sequence for various power supply devices evaluated by the GRA method. Switched-mode power supplies show the highest deviation in power requirements (1.0000) and efficiency (0.9731), reflecting their effective performance; However, they did not record any deviation in noise sensitivity (0.0000). Linear power exhibits significant deviation in noise sensitivity (0.7497) but low scores in efficiency (0.1338) and environmental factors (0.4965). Uninterruptible Power achieves the highest deviation in performance and environmental factors (both 1.0000), indicating strong performance in these areas, while battery packs score zero in all three categories but excel in noise sensitivity (1.0000). Solar power systems show moderate deviations in all metrics, especially environmental factors (0.6251) and noise sensitivity (0.3702).

TABLE 4. Grey Relation Coefficient

	Power requirements	Efficiency	Environmental factors	Noise sensitivity
Switched-mode power supplies	0.3333	0.3394	0.3643	1.0000
Linear power supplies	0.4162	0.7889	0.5017	0.4001
Uninterruptible power supplies	0.5946	0.3333	0.3333	0.4978
Battery packs	1.0000	1.0000	1.0000	0.3333
Solar power systems	0.6801	0.5110	0.4444	0.5746

Table 4 presents the gray correlation coefficient for various power supply devices estimated using the GRA method. Switch-mode power supplies exhibit a strong noise sensitivity rating (1.0000), but low coefficients of power requirements (0.3333) and efficiency (0.3394). Linear power supplies score high in efficiency (0.7889) and moderate in power requirements (0.4162), but have low noise sensitivity (0.4001). Uninterruptible power supply shows balanced performance with coefficients of 0.5946 for power requirements and 0.4978 for noise sensitivity. Battery packs achieve perfect scores on power requirements, efficiency and environmental factors (1.0000), while solar power systems exhibit a good compromise with scores of 0.6801 on power requirements and 0.5110 on efficiency.

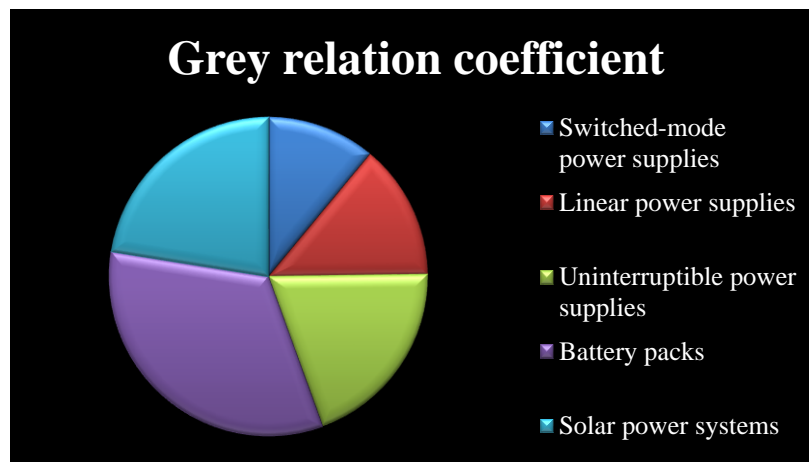


FIGURE 3. Grey relation coefficient

Figure 3 illustrates the gray correlation coefficient for various power supply devices estimated by the GRA method. Switch-mode power supplies excel in noise sensitivity (1.0000), but have lower coefficients for power requirements (0.3333) and efficiency (0.3394). The battery packs score perfect in power, efficiency and environmental factors (1.0000). Linear power supplies score high in efficiency (0.7889), while uninterruptible power supplies maintain balanced performance across categories. Solar power systems offer a good compromise, with coefficients of 0.6801 in power requirements and 0.5110 in efficiency, indicating their overall efficiency in various applications.

TABLE 5. Result of final GRG Rank

	GRG	Rank
Switched-mode power supplies	0.5093	4
Linear power supplies	0.5267	3
Uninterruptible power supplies	0.4398	5
Battery packs	0.8333	1
Solar power systems	0.5525	2

Table 5 presents the final Gray Relation Grade (GRG) rankings for various power supply devices evaluated using the GRA method. The battery packs achieve the highest GRG of 0.8333, ranking first due to their excellent performance in multiple criteria. Solar power systems are a close second with 0.5525 GRG, indicating strong overall potential. Linear Power Supplies ranks third with a GRG of 0.5267, showing good performance and moderate performance. Switch-mode power supplies rank fourth with a GRG of 0.5093, while uninterruptible power supplies rank fifth with a GRG of 0.4398, reflecting their lower efficiency compared to other devices.

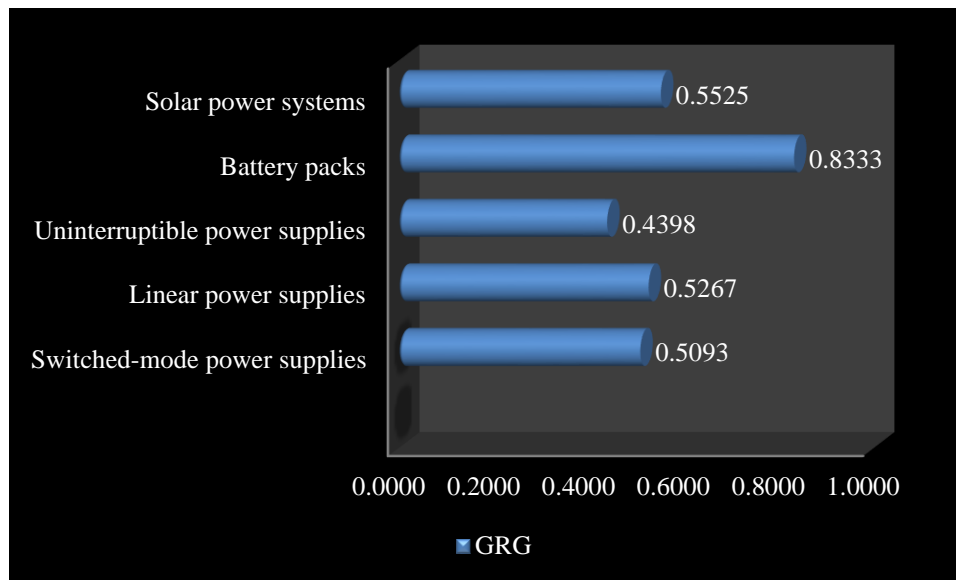


FIGURE 4. GRG

Figure 4 shows the final gray correlation grades (GRG) for various power distribution devices estimated using the GRA method. Battery packs lead the pack with 0.8333 GRG, indicating better performance. Solar power systems follow with a score of 0.5525, while linear power supplies and switch-mode power supplies achieve GRGs of 0.5267 and 0.5093, respectively. Uninterrupted electricity ranks the lowest with a GRG of 0.4398, reflecting their relatively low efficiency.

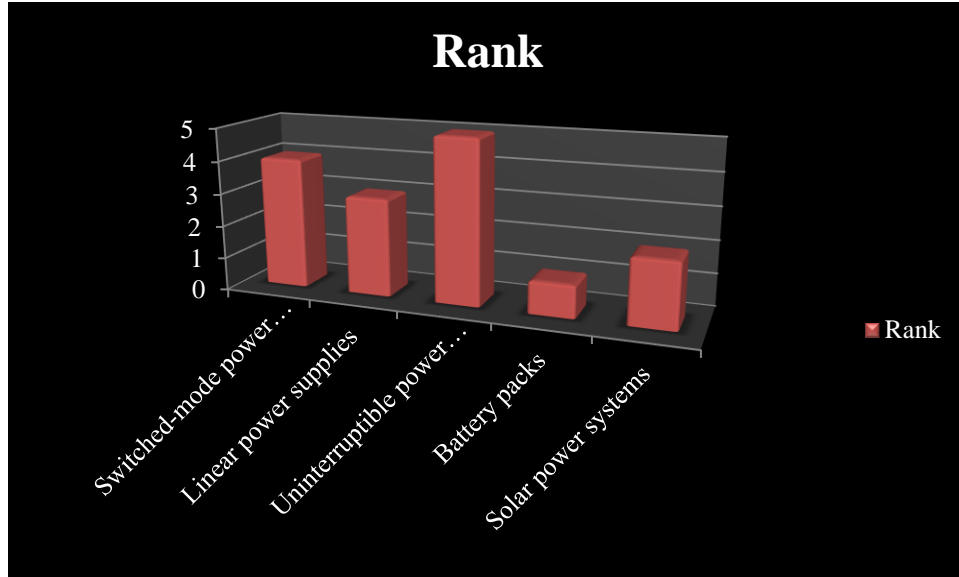


FIGURE 5. Shown the Rank

Figure 5 illustrates the ranking of various power supply devices evaluated by the GRA method. Battery packs are ranked 1st which indicates their excellent performance. Solar power systems are in the second position, while linear power systems are in the third position. Switch-mode power supplies come in at number four, and uninterruptible power supplies at number five.

5. CONCLUSION

The study compared various power supply devices, including switched-mode power supplies, linear power supplies, uninterruptible power supplies, battery packs, and solar power systems. These devices were evaluated based on four key criteria: power requirements, efficiency, environmental factors, and noise sensitivity. Battery packs emerged as the top-ranked power supply option with the highest Gray Relational Grade (GRG) of 0.8333. This indicates that battery packs performed exceptionally well across multiple criteria, offering a balanced combination of power efficiency, environmental friendliness, and adaptability. Their perfect scores in power requirements, efficiency, and environmental factors make them an attractive choice for various applications. Solar power systems secured the second rank with a GRG of 0.5525, showcasing their potential as a sustainable and efficient power supply solution. This ranking reflects the growing importance of renewable energy sources in modern power systems and their ability to balance performance with environmental considerations. Linear power supplies and switched-mode power supplies ranked third and fourth, respectively, with GRGs of 0.5267 and 0.5093. These conventional power supply options still demonstrate competitive performance, particularly in efficiency and reliability, making them suitable for specific applications where their characteristics are advantageous. Uninterruptible power supplies ranked fifth with a GRG of 0.4398, indicating relatively lower overall performance compared to the other options. However, their specific strengths in certain criteria, such as power requirements and noise sensitivity, suggest they remain valuable in scenarios where continuous power supply is critical. This analysis highlights the importance of considering multiple factors when selecting power supply devices for various applications. While battery packs show overall superiority, each type of power supply has its unique strengths that may be more suitable for specific use cases. The study underscores the need for a holistic approach in power supply selection, taking into account not only efficiency but also environmental impact, noise sensitivity, and power requirements. As technology advances and environmental concerns grow, we can expect continued innovation in power supply systems. The strong performance of battery packs and solar power systems indicates a trend towards more sustainable and flexible power solutions. Future developments may focus on improving the efficiency and environmental impact of these leading options while addressing the specific strengths of other power supply types to create more versatile and optimized power solutions.

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