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Power Electronics in Energy Systems: Enhancing Efficiency and Quality in Electrical Energy Conversion and Distribution

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ABSTRACT

Focus is placed on all aspects of electrical energy as well as innovation in energy generation and delivery, three different approaches, and efficient technologies in energy and energy systems research. Research projects focus on systems and equipment for converting, supplying, and using energy as a form of electricity. To increase effectiveness and quality while fostering the gradual materialization of intelligent, efficient energy, power electronics are increasingly a more fundamental component of power systems. Power systems use a wide variety of power electronics. Power systems are the physical study of converting electrical energy from one medium to another. More than 80% of the total electricity produced at a global average rate of 3.4 billion kilowatts per hour per year is reprocessed or recovered in industries like electronics. Electrical energy is processed or converted using power electronics converters, often known as power converters or switching converters. There are two types of electricity: AC power and DC power. Depending on the kind of power it uses, the distribution system is split into AC distribution systems and DC distribution systems.

Once electricity is produced, it needs to be transported from power plants to regional distribution networks over considerable distances. This is accomplished through high-voltage transmission cables, often known as the power grid. High voltages are used on these transmission lines to convey the electricity in order to reduce energy loss during long-distance movement.

Electricity supply chain research refers to the study and analysis of the processes, infrastructure, and systems involved in the generation, transmission, distribution, and consumption of electricity. It aims to understand and improve the efficiency, reliability, sustainability, and cost-effectiveness of electricity supply. The significance of electricity supply chain research can be summarized as follows: Energy Transition and Decarbonisation: As the world shifts towards cleaner and renewable energy sources to combat climate change, understanding the electricity supply chain becomes crucial. Research helps identify opportunities and challenges in integrating renewable energy generation, energy storage systems, and smart grid technologies into the existing electricity infrastructure. Grid Resilience and Reliability: Research on the electricity supply chain focuses on enhancing grid resilience and reliability, ensuring uninterrupted power supply and mitigating the impacts of natural disasters, cyber threats, and other disruptions. It involves studying grid infrastructure, energy storage technologies, demand response programs, and grid management strategies. Energy

Methodology

In this Research we will be using DEMATAL Method.

"Deliver Primary Fuel, Source Primary Fuel, Generate Electricity, Deliver Electricity, Source Electricity"

In this paper, we propose a model of the electricity supply chain that takes into account the interaction between retailers, producers, and end users. The model also takes into account the existence of bilateral contracts, futures, and spot markets, as well as the potential for supply chain coordination through the use of contracts for differences and two-part tariffs. In the context of a case study in the Spanish energy market, we determine the Nash equilibrium of the power supply chain and examine how the existence of futures markets and different contract types affect the market equilibrium.

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INTRODUCTION

The method through which electricity is produced, delivered, distributed, and used is referred to as the electrical supply chain. It entails a number of steps and elements that come together to guarantee a consistent supply of energy to buildings, companies, and industries. Here is a summary of the chain of supply for electricity:

1. Generation: Electricity is largely produced at power plants using a variety of energy sources, including nuclear energy, renewable energy sources (solar, wind, hydropower, and geothermal), fossil fuels (coal, natural gas, and oil), and nuclear energy. These energy sources are transformed into electrical energy in power plants using a variety of devices, including combustion engines, steam turbines, and solar cells.
2. Transmission: After being produced, electricity must be transported over great distances from power plants to regional distribution systems. This is accomplished through high-voltage transmission cables, often known as the power grid. High voltages are used on these transmission lines to convey the electricity in order to reduce energy loss during long-distance movement.
3. Substation: There are substations along the transmission lines where high voltages are stepped down to lower voltages for further distribution. Other tasks carried out by substations include switching, managing, and safeguarding the transmission network.
4. Distribution: In the distribution phase, power is sent from substations to final users, including residences, commercial buildings, and industrial facilities. A given area or region's distribution networks, which provide electricity to numerous areas, are made up of medium-voltage and low-voltage power lines. To further reduce the voltage to levels suitable for consumer usage, transformers are utilized.
5. Metering and Control: Electricity meters are installed at each customer's location to track how much electricity they use personally. These meters offer information on energy usage, enabling clients to get bills that are appropriate. Smart meters and other advanced metering systems allow for two-way communication between the utility company and the customer, enabling real-time monitoring and better energy management.
6. Consumption: At the consumer level, energy is used for a variety of tasks like lighting, heating, cooling, running appliances, powering business operations, and more. The energy bills of end customers are influenced by the electricity they use.

The management and assurance of the energy system's dependability, effectiveness, and safety is the responsibility of regulatory agencies, utility corporations, and grid operators along the electricity supply chain. To provide a consistent and uninterrupted supply of power, these organizations manage production, transmission, and distribution activities. It is important to note that the specific infrastructure, energy sources, and regulatory frameworks in place in various countries and areas can have an impact on the electrical supply chain. The evolution of the power supply chain to support increasingly decentralized and sustainable energy systems is influenced by the growing integration of renewable energy sources and the advancement of smart grid technology.

As Watson and Zheng showed in 2005, the sharing of real-time sales data may enhance supply chain coordination by removing information delays. Balakrishnan et al. (2004) examined how supply chain coordination can be utilized to reduce demand uncertainty and developed a downstream inventory smoothing system to reduce order size variability using a supply chain with one supplier and numerous retailers as the study's base. To determine if a manufacturer could benefit from exchanging information with a retail consumer, Kulp et al. (2004) conducted a survey. They discovered that while cooperative replenishment planning is linked to higher manufacturer margins, it typically leads to higher wholesale pricing and fewer store and manufacturer stockouts. The coordination of supply chain activity may be enforced using contracts: "A contract is said to coordinate the supply chain if the set of supply chain optimal actions is a Nash equilibrium," according to Cachon (2003, p. 230). The agreement should be drafted so that, if signed by the parties, it Pareto dominates the non-coordinated Nash equilibrium. According to Cachon (2003), providing these two elements in a contract might be very expensive. As a result, a less ideal contract that is close to the ideal solution may be preferred.Zhang (2006) investigated the role of information sharing in supply chain coordination and found that the Nash equilibrium exists but is not ideal. Additionally, it is shown that the Nash equilibrium yields perfect coordination via a transfer payment contract. Taking into account a single supplier and manufacturer, Miyaoka and Hausman (2008) investigated the effects of consumer demand uncertainty on supply chain coordination under various assumptions for the development of wholesale prices, demonstrating how knowledge sharing increases the supply chain profit and presenting a pact that allows flexibility in giving away the supply chain benefit among its members. It is still a contentious topic to argue how futures and spot markets affect corporate strategy and societal welfare. When there is a concentrated generation market structure, Allaz (1992) and Allaz and Vila (1993) claim that the introduction of futures markets causes a decrease in spot equilibrium prices.

MATERIALS AND METHOD

Deliver Primary Fuel: From the main storage terminals, petrol is often transported by tanker truck to the smaller blending terminals, where it is converted into finished motor petrol. Typically, fuel ethanol is mixed into petrol at these smaller terminals**.**

Source Primary Fuel: Primary energy sources can be nuclear, conventional (such as coal, oil, and gas from the earth), or sustainable (such as solar power, geothermal energy, wind power, and hydropower). They also come in a range of sizes and shapes.

Generate Electricity: "The majority of the world's energy is produced by steam turbines using fossil fuels, nuclear power, biomass, geothermal, and solar thermal energy." Some of the more important energy production technologies are solar photovoltaics, gas turbines, hydro turbines, and wind turbines.

Deliver Electricity: Electricity distribution is the procedure that takes place after energy is generated at a power plant and continues all the way to the consumer's use. The following are the main steps of power supply, in that order: Transmission.

Source Electricity: "Nuclear energy, renewable energy sources, and fossil fuels (coal, natural gas, and petroleum) are the three main energy sources utilized to produce electricity. The majority of the world's energy is produced by steam turbines, which also use fossil fuels, nuclear energy, biomass, geothermal energy, and solar thermal energy."

DEMATAL method: Most businesses will always require capable global managers to handle the effects of current and upcoming breakthroughs in globalization (Harvey, Novice Vic, &Kissing, 2002). Finding and keeping a sufficient number of capable global managers is essential for organizations to be able to compete successfully in the global market. Businesses must successfully implement global manager selection with multiple intelligences as unique competences and support global managers in identifying and developing their skills if they hope to maintain a sizable workforce of competent global managers. These articles all support the idea that the presence of futures markets lowers prices and improves social welfare in oligopolistic industries. According to Gallinari and Oliveira's (2012) research on the link between future and spot markets, risk-averse generators trade more in the futures market and generate more than risk-neutral generators when the generators are homogeneous. The subject of twofold marginalization in supply chains has been researched in relation to creating coordinating mechanisms. Double marginalization and retailer externalities (i.e., the stockpiling decisions of one store affect the earnings of the other shops) were two sources of inefficiencies that Intestine and Zhang (2005) discovered. "They accomplished this by investigating a supply chain that featured a wholesale manufacturer, numerous retailers, and stochastic demand. They have concluded that when there is retailer competition and positive externalities, supply chain coordination is more important. Chen et al. (2006) suggested a risk-sharing agreement for a supply chain involving a manufacturer and an outlet store in which the manufacturer compensates the retailer in the occurrence of overstocking and the retailer compensates the manufacturer in the event of overproduction. This would prevent double marginalization." Heese (2007) examined the double marginalization issue in a supply chain (where a Stackelberg manufacturer sets the wholesale price and a retailer chooses how much inventory to sell) and came to the conclusion that inventory errors aggravate this issue. He has also looked at the conditions under which double marginalization makes it more difficult for the supply chain to deploy computerized inventory control. "The approach most usually used to handle the double marginalization issue is the two-part tariff contract, in which the retailer pays the producer a set access charge for the right to purchase its output as well as a per-unit price for each unit of production the retailer purchases. However, the oligopoly example's solution to the two-fold marginalization problem is challenging and industry-specific; for example, see Rey and Vergé (2005)."

RESULTS

TABLE 1. Data Set

	Deliver Primary Fuel	Source Primary Fuel	Generate Electricity	Deliver Electricity	Source Electricity	SUM
Deliver Primary Fuel	0	4	3	4	4	15
Source Primary Fuel	3	0	5	3	3	14
Generate Electricity	3	4	0	2	3	12
Deliver Electricity	2	3	4	0	2	11
Source Electricity	3	2	2	3	0	10

"Table 1 shows DEMATAL Method with respect to delivery primary fuel, source primary fuel, generates electricity, source electricity and deliver electricity. The total of all the parameters with high values. The highest value is seen in table 1, where 15."

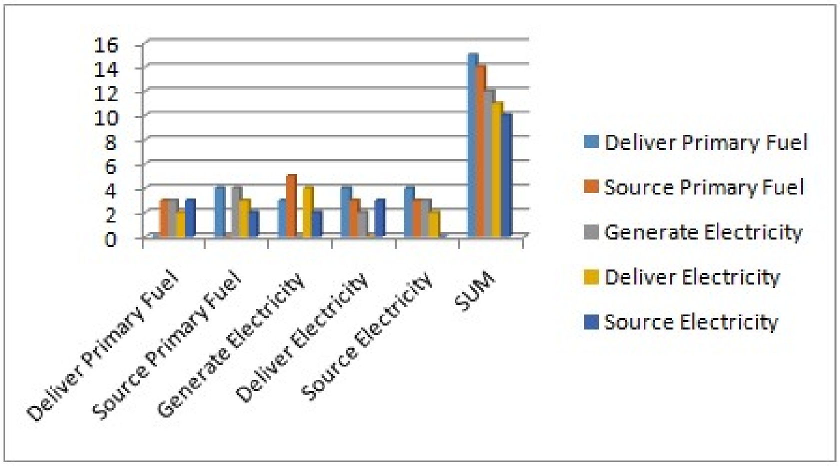

FIGURE 1. Data Set

Figure 1 shows DEMATAL Method with respect to "delivery primary fuel, source primary fuel generates electricity source electricity," It is an assessment and comparison of any two facilities.

TABLE 2. Normalization of direct relation matrix

	Deliver Primary Fuel	Source Primary Fuel	Generate Electricity	Deliver Electricity	Source Electricity
Deliver Primary Fuel	0	0.266666667	0.2	0.266666667	0.266666667
Source Primary Fuel	0.2	0	0.333333333	0.2	0.2
Generate Electricity	0.2	0.266666667	0	0.133333333	0.2
Deliver Electricity	0.133333333	0.2	0.266666667	0	0.133333333
Source Electricity	0.2	0.133333333	0.133333333	0.2	0

Table 2 shows DEMATAL Method Normalization of direct relation matrix with respect to delivery primary fuel, source primary fuel generate electricity, source electricity; Figure 2 shows that all of the data's diagonal values are zero. Consider the Y Value in Table 2.

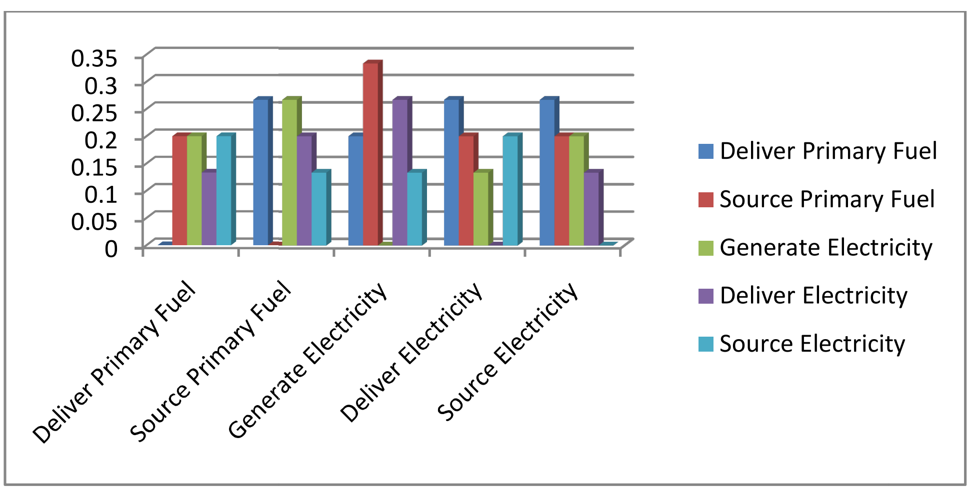

FIGURE 2. Normalization of direct relation matrix

TABLE 3 I= Identity matrix

1	0	0	0	0
0	1	0	0	0
0	0	1	0	0
0	0	0	1	0
0	0	0	0	1

Table 4 given that the Identity matrix the matrix diagonal line got values one other values is zero.

TABLE 4

Deliver Primary Fuel	1.859173606	1.1966572	1.2209315	1.1237275	1.1291277
Source Primary Fuel	0.983589027	1.9406047	1.2554715	1.0254541	1.0382329
Generate Electricity	0.895046766	1.0467342	1.8909868	0.8891119	0.9447716
Deliver Electricity	0.787256188	0.9368049	1.0342228	1.7013909	0.8309926
Source Electricity	0.779770731	0.8250043	0.8705586	0.8202991	1.6564247

Table 7 calculated the (I-Y)-1 value. All values are negative but diagonal line values are positive values.

TABLE 5 total correlation matrix

	0.859173606	1.1966572	1.2209315	1.1237275	1.1291277
Deliver Primary Fuel	0.983589027	0.9406047	1.2554715	1.0254541	1.0382329
Source Primary Fuel	0.895046766	1.0467342	0.8909868	0.8891119	0.9447716
Generate Electricity	0.787256188	0.9368049	1.0342228	0.7013909	0.8309926
Deliver Electricity	0.779770731	0.8250043	0.8705586	0.8202991	0.6564247

"Table 8 shows the total correlation matrix, the direct correlation matrix, Multiplied by the inverse of the direct correlation matrix value subtracted from the identity matrix."

TABLE 6 Ri and Ci

	Ri	Ci
Deliver Primary Fuel	5.5296175	4.3048363
Source Primary Fuel	5.2433522	4.9458053
Generate Electricity	4.6666512	5.2721712
Deliver Electricity	4.2906674	4.5599835
Source Electricity	3.9520574	4.5995494

"The table provides data on the values of Ri and Ci for different activities related to fuel and electricity. Ri represents the reliability index, while Ci represents the cost index." When it comes to delivering primary fuel, the reliability index (Ri) is 5.5296175, indicating a high level of reliability in this process. The cost index (Ci) is 4.3048363, suggesting that it is relatively cost-effective. In terms of sourcing primary fuel, the reliability index is slightly lower at 5.2433522, but still within a reliable range. The cost index, however, is higher at 4.9458053, indicating that this process may be slightly more expensive. Generating electricity has a reliability index of 4.6666512, suggesting a good level of reliability. The cost index for this activity is 5.2721712, indicating that it may be relatively expensive to generate electricity. When it comes to delivering electricity, the reliability index is 4.2906674, which is still within an acceptable range. The cost index for this process is 4.5599835, suggesting that it is reasonably cost-effective. Lastly, in terms of sourcing electricity, the reliability index is 3.9520574, which is lower compared to the other activities. However, it still indicates a moderate level of reliability. The cost index for this activity is 4.5995494, suggesting that it may be moderately expensive to source electricity. Overall, the data highlights the reliability and cost factors associated with different activities related to fuel and electricity. It provides insights into the performance and expenses involved in delivering, sourcing, and generating these essential energy resources.

TABLE 7. Ri+Ci and Ri-Ci

	Ri+Ci	Ri-Ci
Deliver Primary Fuel	9.8344538	1.2247811
Source Primary Fuel	10.189157	0.2975469
Generate Electricity	9.9388224	-0.60552
Deliver Electricity	8.8506509	-0.269316
Source Electricity	8.5516069	-0.647492

Table 7 presents the values of Ri+Ci and Ri-Ci for various activities related to fuel and electricity. Ri+Ci represents the sum of the reliability index (Ri) and the cost index (Ci), while Ri-Ci represents the difference between the two. For the activity of delivering primary fuel, the value of Ri+Ci is 9.8344538, indicating a high overall performance that combines both reliability and cost factors. The Ri-Ci value is 1.2247811, suggesting that the reliability index contributes more significantly to the overall score than the cost index in this case. In the case of sourcing primary fuel, the Ri+Ci value is 10.189157, indicating a relatively strong performance when considering both reliability and cost. The Ri-Ci value is 0.2975469, suggesting that the cost index has a smaller impact on the overall score compared to the reliability index. For generating electricity, the Ri+Ci value is 9.9388224, indicating a good overall performance in terms of reliability and cost. Interestingly, the Ri-Ci value is negative (-0.60552), indicating that the cost index outweighs the reliability index, potentially suggesting higher costs associated with this activity. When it comes to delivering electricity, the Ri+Ci value is 8.8506509, indicating a slightly lower overall performance compared to the other activities. The Ri-Ci value is also negative (-0.269316), suggesting that the cost index has a more significant impact on the overall score in this case. Lastly, for sourcing electricity, the Ri+Ci value is 8.5516069, indicating a relatively moderate overall performance considering both reliability and cost. The Ri-Ci value is also negative (-0.647492), highlighting the influence of the cost index in determining the overall score.In summary, Table 7 provides a comprehensive view of the combined reliability and cost aspects of different activities related to fuel and electricity. It allows for a comparison of the overall performance and the relative importance of reliability and cost factors in each activity as seeing figure 4.

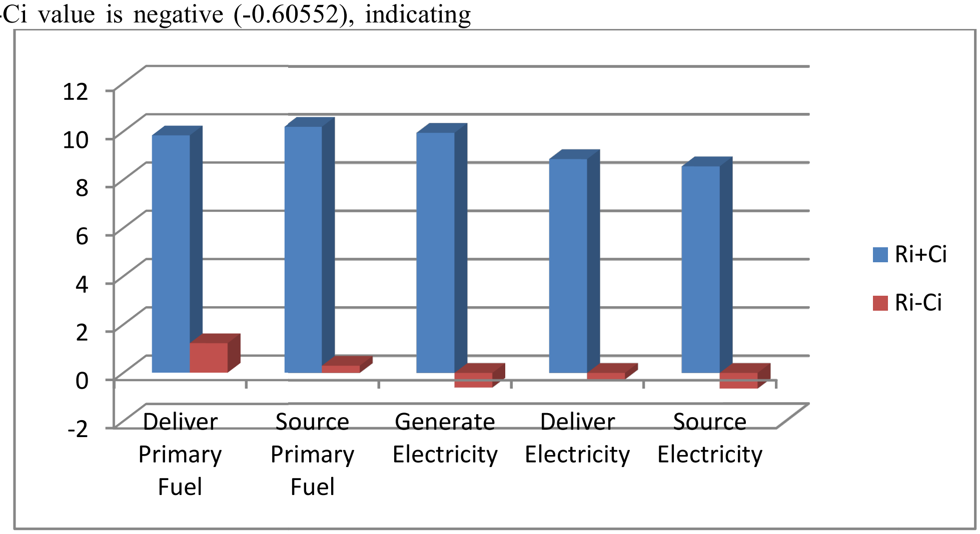

FIGURE 4. Ri+Ci and Ri-Ci

TABLE 8. Rank

	Rank
Deliver Primary Fuel	3
Source Primary Fuel	1
Generate Electricity	2
Deliver Electricity	4
Source Electricity	5

Table 8 given ranking Source Primary Fuel for a first rank, Generate Electricity for a second rank, Deliver Primary Fuel for a third rank, Deliver Electricity for a fourth rank and Source Electricity for a fifth rank, seen in figure 5.

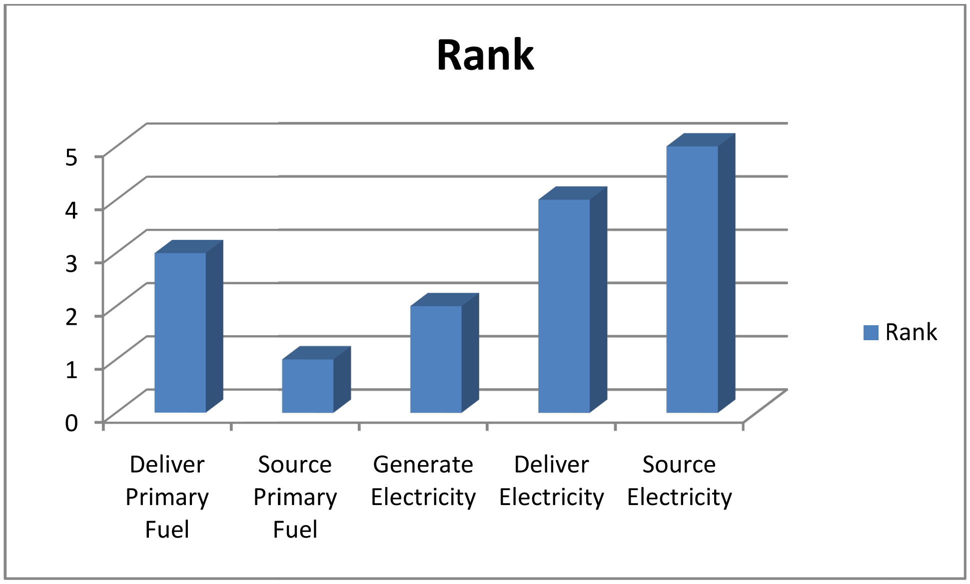

FIGURE 5. Rank

CONCLUSION

In this paper, "we propose a model of the electricity supply chain that takes into account the interaction between retailers, producers, and end users. The model also takes into account the existence of bilateral contracts, futures, and spot markets, as well as the potential for supply chain coordination through the use of contracts for differences and two-part tariffs.In the context of a case study in the Spanish energy market, we identify the Nash equilibrium of the power supply chain and analyze how the existence of futures markets and different contract types affect the market equilibrium." The electricity supply chain is a significant one that deals with power as a perishable good. This study provides an integrated method for examining a power supply chain. This study uses a thorough analysis of the electrical supply chain to comprehend how various activities are interdependent. This is already the main motivation behind the SCM approach in every firm. Since the product is extremely perishable and cannot be easily kept in large numbers, the necessity for coordinated operations will be especially crucial in an electrical supply chain. Therefore, it is crucial to look into the possibilities of the SCM literature's defined concepts for an electrical supply chain. Although the suggested framework's generic structure components, such as its basic processes and horizontal organization, won't be situation-specific, Analysts might benefit from other case-specific aspects in order to develop a well-organized view on a particular scenario. The power supply chain is used to illustrate how the advanced planning framework is applied to show how these activities must be coordinated and how they are interdependent for planning tasks across different time horizons.

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