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THE ROLE OF THE DEMAND SIDE MANAGEMENT AND ENERGY STORAGE SYSTEM IN THE OPTIMIZATION OF THE GRID STABILITY IN JORDAN ACCORDING TO A PARTIALLY PUBLIC SURVEY

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ABSTRACT

The high growth in demand for electricity associated with its dependence on conventional ways of production is likely to grow in Jordan as a result of the increase in the number of development investment projects, as well as the increase in the number of consumers. That would probably increase CO_2 emissions, as well as lower the expenditures on energy sources on the part of the consumers. In Jordan, the adoption of renewable energy systems (RES) has tremendously grown over the past few years. In this research paper, the demand-side management (DSM) and energy storage system (ESS), including superconducting magnetic energy storage (SMES), were discussed about how they can help satisfy increasing energy demand and improve grid reliability. Due to this reason, a sample of individuals residing in Jordan was surveyed on their wellness and acceptance of the implementation of DSM. The survey findings indicated that 71.7 percent of the 385 respondents to the survey indicated that they would be willing to join such a program in case it were available in Jordan. It can be mentioned that the government of Jordan has already started to realize the demand-side management (DSM) strategy that is to be discussed in the current work by connecting the energy prices with the time of consumption in a day. This study discusses one of the most important forms of energy storage systems (ESS), the superconducting magnetic energy storage (SMES), as a long-term response to the growing demand for clean energy and punctual peaks.

Keywords: CO_2 emissions, renewable energy systems (RES), demand side management (DSM), energy storage systems (ESS), superconducting magnetic energy storage (SMES).

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1. INTRODUCTION

The electrical energy consumption in Jordan continues to surge in line with a global trend. According to NEPCO's annual reports, the recorded peak load consumption in Jordan in 2021 reached 3770MW, marking a 3.71% increase compared to the previous year [1, 2]. Among all sectors, the "governmental and household" sector accounts for the highest consumption at 44.49% [2]. Jordan heavily relies on imported natural resources for its energy needs, but there has been a gradual decline in recent years due to an increased utilization of renewable energy sources. Indeed, by 2018, renewable energy sources had contributed 92 percent of the country's energy mix [3]. The renewable energy systems (RES) development in Jordan is increasing, as Jordan intends to cut down carbon emissions and environmental impact with respect to the goal of the Paris Agreement to restrict global warming to 1.5 °C and reach net-zero emissions by 2050 [4]. In 2021, the share of renewables in the total energy production of the country was 28.7 percent [5]. This presents a large problem to the Jordanian grid, because the utilization of renewable energy sources as a source of supply complicates the possibility of aligning the demand [6], principally because the main renewable energy sources utilized in Jordan (Wind and Solar) are weather-dependent.

Jordanian transmission grid code states that the allowed range of voltage fluctuations on the transmission system shall be:

1) ± 5% for 400 kV and 230 kV lines.
2) ± 10% for 132 kV lines.

Plus an additional allowance of 5 per cent. When the system is under stress or after a fault [9]

Several alternatives have been found to solve this problem, and one of the major alternatives is the demand-side management (DSM) [7]. DSM regulates and operates consumer electrical usage, altering their patterns of consumption so that they coincide with electricity production.

The other solution that is widely under investigation is the application of Energy storage systems (ESSs) to store the surplus energy generated by renewable energy sources (RES) when the demand is low or generation is at its peak and later release it when the demand is high or when there is inadequate generation [8].

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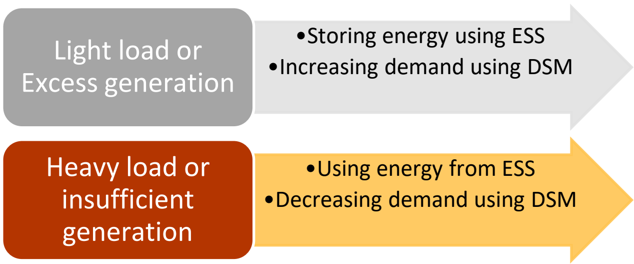

Figure-1. Proposed Solutions.

2. DEMAND SIDE MANAGEMENT (DSM)

DSM is employed in managing the demand; it can either reduce or increase the demand to equate to the generation of electricity. It may be described as follows: a collection of methods that may be employed to alter the shape of consumption of electricity end-users over time [10]. In order to curtail high demand during certain periods, many countries have had to implement demand-side management programs, which make use of a number of principles, such as mandatory and optional agreements between the distribution company and the customer [13]. DSM has two key branches, which are Energy Efficiency (EE) and Demand Response (DR) [11]. This allows the customers or consumers to become part of the electrical grid and be able to affect the grid by making decisions that may shift, add, or reduce demand. There are three types of DR programs, and they rely on the reason why the consumer should change their load:

a) Incentive-based programs: In these programs, consumers are given incentives to change their consumption behavior within a given period. The rewards or incentives may be given in credits or monetary form.

b) Market-Based Programs: In this case, through dynamic pricing, the electrical tariff varies according to the level of demand and that of generation. This makes consumers alter their consumption, as they respond to pricing signals that they receive.

c) Price-Based Programs: Various rates would be charged at various times of the year. During peak periods, rates are hiked, and during off-peak periods, rates are reduced. The journal has referees who are recognized experts in the field to review manuscripts submitted. IEJ also has an online journal system in which it not only has the current volumes, but it also archives the past volumes and special issues.

Table-1. Electricity generation mix in Jordan (2021).

Energy Source	Percentage Contribution
Renewable Energy	28.7%
Fossil Fuels	71.3%

2.1 Demand Response (DR)

DR is among the simplest and effective remedies that can be adopted to enhance the reliability of our electric grid. Nonetheless, it continues to encounter a lot of problems in implementation. These difficulties may either be technical or social.

Technical issues entail the development and establishment of proper disaster recovery (DR) initiatives. Among these issues are the ability to create reliable communication systems, the creation of real-time and accurate data monitoring systems, and the ability of disaster recovery (DR) to be smoothly integrated into already existing grid systems.

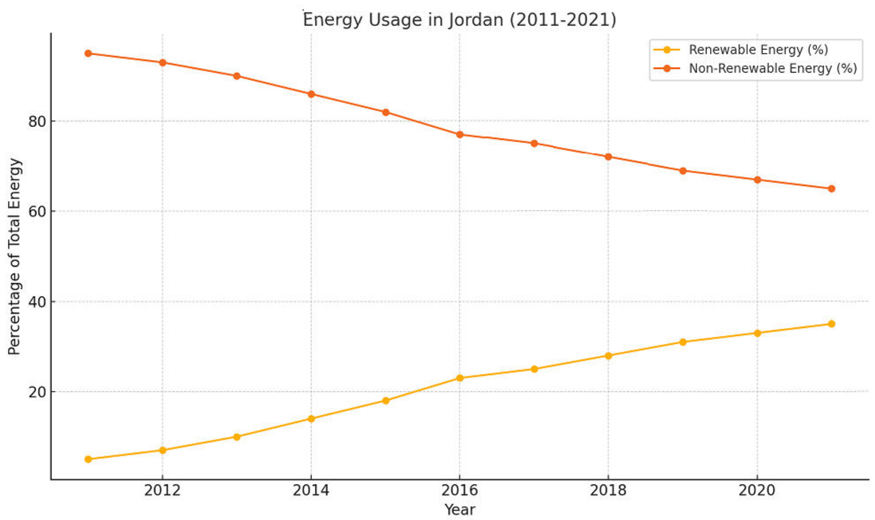

Figure-2. Energy usage in Jordan (2011-2021).

Social issues relate to the behavior of people and the acceptance of DR programs. Encouraging End-user involvement and participation must be achieved through communication, education, and incentives. Addressing change reflexes and establishing the culture of energy conservation and responsiveness are essential to achieving the demand response (DR) adoption success.

It is possible to distinguish the following types of DR programs depending on their functions [12]:

A. Peak load clipping: It is a kind of Demand Response (DR) that is implemented during peak loads to decrease electricity demand and align it with the normal consumption profile. Peak load clipping can be used to reduce the stress on the grid during high-demand times by reducing non-essential loads, or institutions may opt to employ load-shedding schemes.

B. Load shifting: The load-shifting demand response (DR) programs are also applied during the peak-load times. The aim is to move consumer electric demand off-peak so as to balance the load curve. Load shifting achieves this by encouraging consumers to shift their usage patterns to more evenly spread demand across the day, optimizing grid operations, and avoiding the requirement to build more generation capacity.

C. Valley filling, load building, or flexible load: This demand response (DR) type is applied in cases of excess generation of renewable energy sources (RES) production. It is expected to motivate the end-users to consume more electricity so as to utilize the surplus generation capacity. The Valley filling program helps to maximize the use of clean energy sources by matching consumer demand with the availability of renewable energy resources and helps to ensure grid stability.

The diversification and implementation of these demand response (DR) strategies can yield a variety of benefits such as grid reliability, decrease in peak demand, energy efficiency, and more renewable energy sources integration. Addressing the technical and social issues that surround the implementation of DR is seen as a key to tapping into the full potential of this concept and achieving a more sustainable and resilient electrical grid.

2.2 Price-Based DR Programs

Demand response (DR) programs that rely on price are grounded on the concept of varied prices of electric tariffs at different times [14]. They mainly include:

A. Time-of-use (TOU) pricing: It is one of the types applied in the implementation of a price-based program, which relies on the concept of dividing a day into several periods. A particular number of hours is included in each period, and this number is defined by high demand, and the customer is charged for hours of consumption during the periods at a price higher than during consumption outside high-demand periods. By this, the consumers can be motivated by us to reshape their consumption time during the peak time. [14]

B. Real-time pricing (RTP): This type is used in the application of the price-based program, which is based on the principle of dividing the day into 24 hours, with each hour having a different price that depends on high demand. The customer must be notified of the price per hour separately [14]. One of the concerns customers have about this system is the possibility of significant fluctuations in hourly tariff rates. Some companies applying this system have resorted to charging a fixed price for basic consumption, with any consumption above the basic level being subject to the RTP system [16]. When applying the RTP program, one of the factors to consider is announcing the hourly tariff price before the hourly time begins [16]. One of the drawbacks of this system is that the monthly bill may increase due to price fluctuations, which makes it unacceptable to customers. [15]

C. Critical peak pricing (CPP): This system operates similarly to the TOU system, but with a slight difference: it is only applied during periods of danger on the electrical network (occurring several times per year) and imposes huge fees. [14]

3. ENERGY EFFICIENCY IN DEMAND SIDE MANAGEMENT

3.1 Definition

In Demand Side Management (DSM), energy efficiency refers to the strategies and techniques used to lower end-user energy consumption without reducing their quality of service or comfort. Energy efficiency can involve altering consumption habits to more efficient ones, such as using energy-saving LED lighting in households or installing thermal insulation to reduce energy consumption for cooling or heating homes. By switching from fixed (demand-independent) electricity prices to more dynamic pricing strategies, price-based demand response (PBDR) methodologies seek to flatten the demand profile. [18]

Definition 1. (Economic Efficiency). If an allocation rule maximizes the social welfare of its agents, the mechanism is considered efficient. The sum of the utilities of the participating agents is the social welfare. [19]

$$ui(si,s-i)=vi(si,s-i)-pisi \quad (1)$$

Where:

ui :is the price for the service offered by player i.
si : Does the player take the action I?
s-i : is the action vector of all other players except player i.
vi : is the valuation function of player i.
*pi*is the price for the service offered by player i.

Definition 2. (Direct Revelation). The product allocations that guarantee maximum Social welfare can be determined by solving the optimization problem in the equation above. Nevertheless, the private preferences that are necessary to resolve this issue are not accessible to the mechanism designer. The principal will merely request that the agents provide their personal information as part of their bid space in a direct reveal process. This simplifies the task of designing the mechanism, but because each agent is selfish, it also raises the possibility that agents may feel pressured to report their private types dishonestly. Agents must be encouraged to report their types honestly. Otherwise, the mechanism's effectiveness will be compromised. This limitation is referred to as the incentive compatibility constraint. In contrast, indirect methods protect privacy by not requiring agents to disclose their data fully. This can be accomplished by using a multicount technique to gather incremental data from the agents.

Definition 3. (Incentive Compatibility). This restriction is necessary to ensure economic efficiency and the veracity of direct procedures. The mechanism designer must ensure that agents do not profit from false bidding, guaranteeing that they report their private types correctly while acting in their self-interest. This restriction is written as follows:

$$ui(qi, \theta i) \geq ui(qi, \theta)$$

This means that the utility an agent receives while reporting their actual type, $ui(qi, \theta i)$, is always greater than the value they receive when bidding dishonestly, $ui(qi, \theta)$. [20]

Definition 4. (Individual Rationality). A desired characteristic of processes where involvement is optional is individual rationality (IR), also known as participation constraint. It guarantees that agents acquire at least the same benefit from participating as they would from not doing so. Considering that an agent receives no benefit from abstaining, an IR restriction can be written as [21]:

$$ui\ (qi, \theta i) \geq 0$$

3.2 Review of Mechanisms

Indirect mechanisms typically experience efficiency losses because they only request a portion of the information necessary to solve the optimal social welfare issue (as stated in the Equation above), which necessitates full knowledge of the participating agents' private utilities.
In [22, 23], for instance, according to the author, when a client reports their deadline-differentiated demand in response to a supplier's non-increasing deadline-differentiated pricing bundle (i.e., a lower price for demand with a more extended deadline), the DSM mechanism is effective. The optimum price package is then determined using the supplier's ideal supply curve and the expected RE generation. However, the procedure functions on the tacit assumption that customers don't care if their demand is met before or on the scheduled date.
For the majority of consumers, who would want to have their duties completed as soon as possible, this is probably not the case. Consequently, user welfare losses could occur, rendering the mechanism ineffective and undesirable in practice.

In a microgrid [24, 25], a double auction is suggested for prosumers to trade energy. In this approach, the coordinator announces initial supply requirements and prices to producers, as well as initial demand allocations to consumers. Then, buyers bid their best rates for the assigned demand, while suppliers bid their best offers for the energy supply at the set price. The coordinator then updates the energy allocations and market price by solving the supply and demand optimization (SWO) problem. This process is repeated until a convergence condition is fulfilled. This mechanism has some drawbacks, one of which is the assumption that agents are price takers in their activities.

It has no bearing on market prices. But, in practice, agents can be strategic and possibly foresee how their actions will affect the market. Another drawback of this mechanism is its centralized control over final allocations. If agents decide not to follow these allocations because of uncertainty in supply or demand, this could result in efficiency losses [26].

Presents a posted price system for energy markets. At each time interval that agents (arriving at various phases) can take or leave, the authors design ideal price profiles. Despite the mechanism's ability to withstand demand fluctuations and maintain privacy, it loses efficiency because agents' partial preferences are known.

By using a Markov decision process to simulate the strategic interactions between the station and the connected electric vehicles (EVs), the authors of [10] propose a pricing system for EV charging stations. Although the charging station's long-term revenue can be maximized by this pricing method, the social welfare of its consumers is not.

[27] Proposes a DSM model in which consumers schedule their electricity usage on an individual basis. The suggested plan takes into account customer choices while protecting their privacy. Nevertheless, since it doesn't examine how this consumer-centred strategy impacts social welfare, inefficiency at the societal level may be caused by a lack of coordination among customers.

4. SURVEY ON DEMAND SIDE MANAGEMENT PROGRAMS

4.1 Participants' Backgrounds

4.1.1 The nationality of the participants

One of the most crucial aspects of demand-side management is the willingness of people to participate in these programs. To assess this, a Demand Side Management program survey was conducted in the Hashemite Kingdom of Jordan. A total of 385 individuals from various backgrounds residing in Jordan participated in this survey, as shown in Table-2.

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Table-2. The nationality of the participants.

Nationality	Jordanian	Palestinian	Syrian	Libyan	Saudi	Yemeni	Egyptian
Participants Number	370	7	4	1	1	1	1

Given that 30.6% of Jordan's population consists of immigrants, it is essential to gather their opinions on these programs [29].

4.1.2 Age of participants

It is essential to determine the age of participants to evaluate their likelihood of engagement in these programs. Figure-3 shows the age of the participants.

Based on the research, it was found that respondents aged 25 or younger comprised the largest group in the poll, accounting for more than 50% of all respondents. Therefore, it is likely that implementing similar initiatives among Jordan's next generation would yield positive results. Furthermore, given that 32% of participants were between the ages of 45 and 65, the initial deployment can be initiated immediately.

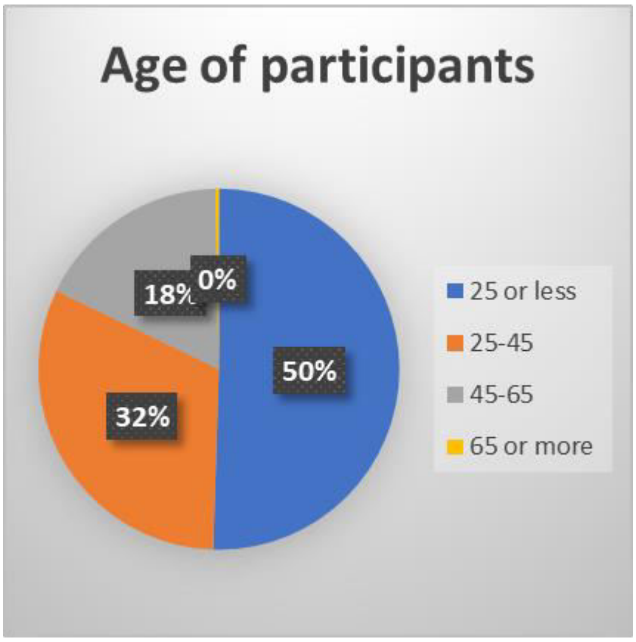

Figure-3. Age of participants.

4.1.3 The participants' educational background

It is essential to determine the participants' educational backgrounds to identify the most effective means of communication and presentation for these programs. Figure-4 displays the participants' academic backgrounds.

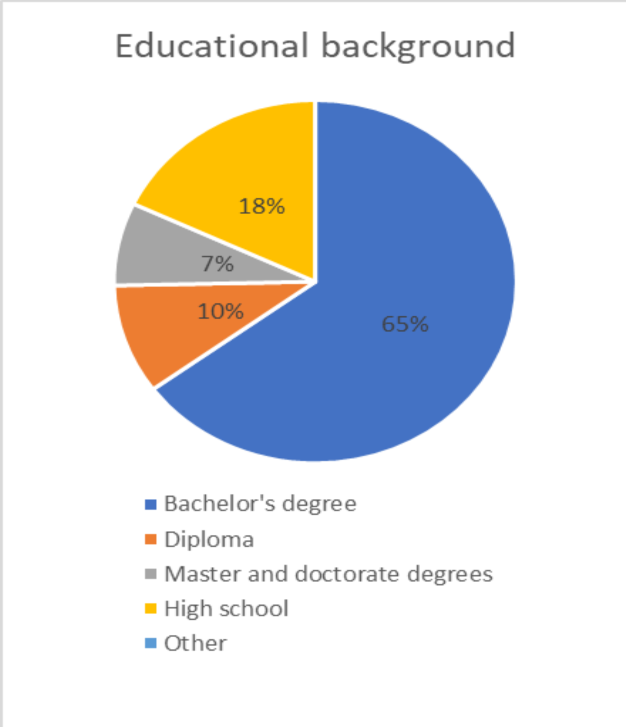

Figure 4. Educational background of participants.

4.1.4 Geographical distribution of participants

Knowing the geographical distribution of participants within Jordan is a crucial factor in determining the program's starting point, identifying areas that require greater advertising efforts, and planning subsequent steps. Table-3 provides insight into the participants' current locations within the country.

As shown in Table-3, it's easier to start in a central region (Amman, Zarqa, Balqa, Madaba) than in the northern region (Irbid, Mafraq, Jerash, Ajloun) or the southern region (Karak, Aqaba).

Table-3. Geographical distribution of participants.

Amman	Balqa	Madaba	Zarqa	Irbid	Mafraq	Jerash	Ajloun	Aqaba	Karak
56.5%	30.1%	3.4%	2.3%	2.3%	0.3%	1.8%	0.3%	1.6%	0.8%

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4.1.5 The financial background of the participants

Given that the programs are incentive-based, market-based, and price-based, with a primary focus on the financial aspect, it is essential to gather information about the participants' economic backgrounds. This data will enable us to determine the most suitable program for successful deployment in Jordan.

4.1.6 The participants' home ownership status

Another critical factor to consider is the home ownership status of the participants. Findings indicate that 81.6% of the participants own their homes, while 18.4% are renting. Notably, individuals who own their homes are more likely to remain engaged in the program for an extended duration compared to those who rent their homes.

4.1.7 Monthly income

Income is a primary factor influencing people's decision to participate in the program. Financial incentives might encourage people with lower incomes to participate. The data show that 55.4% of participants have an income of 500 JD or above, who may prefer different types of programs than the 44.6% of participants with a lower monthly income.

4.2 What Do Participants Think About Demand-Side Management?

Participants were asked about their prior knowledge of DSM programs. Among the 385 participants, 84.4% reported having no prior knowledge of these programs, while 15.6% stated that they had some previous knowledge of them.

4.2.1 Indirect load control

Indirect load control includes programs where an agreement is made in advance with consumers to monitor and regulate their consumption during agreed-upon times. Such programs were explained to the participants, and 71.7% responded positively, indicating their willingness to participate. On the other hand, 28.3% responded negatively. Among those who approved, Figure-5 shows the reasons for their agreement. The primary reason for approval was the potential for a reduced electricity tariff, suggesting that a program offering this benefit could be successful in Jordan and contribute to energy conservation and environmental sustainability. Approximately 23% of participants were motivated solely by this reason. Additionally, a significant number of participants expressed interest in programs that combined two or more of the reasons suggested in the survey.

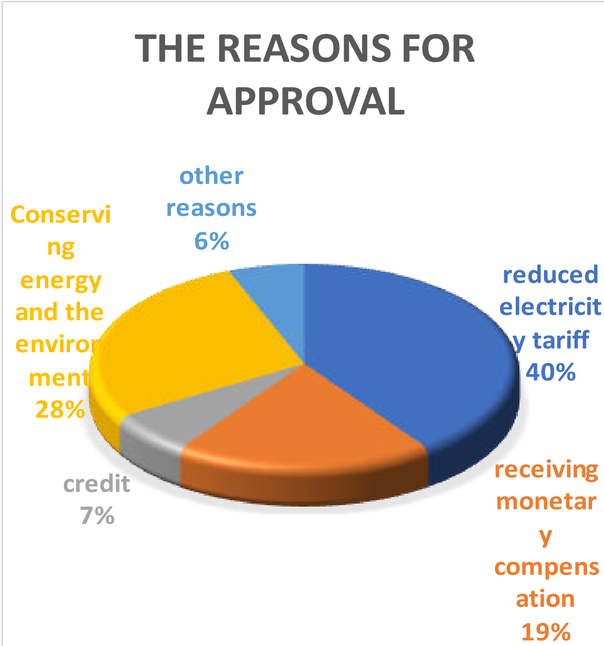

Figure-5. The reasons for the approval of indirect load control.

According to Figure-6, the main reasons for participants' unwillingness to engage in the programs are a lack of knowledge about the program and a lack of trust in the responsible companies. These factors pose significant barriers to participation. By addressing these concerns and focusing on increasing awareness and building trust, we can potentially convince more individuals to participate in the programs. We asked participants if they would continue to support the idea if penalties were imposed for non-compliance with the agreed-upon time. The results showed that 62.9% of participants stated they would not continue to support the idea under these circumstances.

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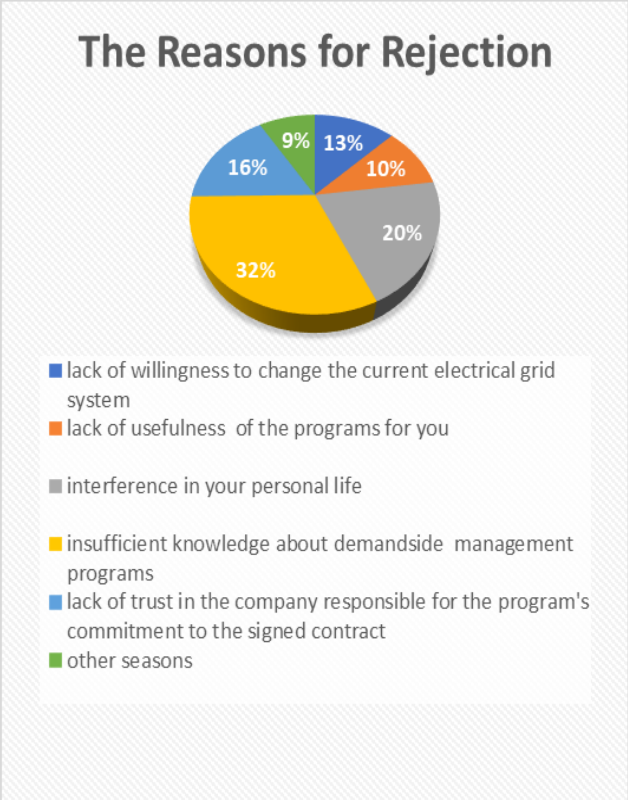

Figure-6. Reasons for rejecting indirect load control.

4.2.2 Direct load control

In this survey, participants were also asked about their willingness to participate in a program where the responsible company would have direct control, such as setting temperature limits for air conditioning or disconnecting certain appliances without prior notification. In exchange, participants' electricity consumption would be regulated, and they would receive either a greater reduction in the electricity tariff or greater monetary compensation compared to the previous phase. The results revealed that 51.9% of participants responded negatively to this proposition, as indicated in Figure 7, citing various reasons. However, 48.1% of participants responded positively to the idea, as shown in Figure 8. Upon comparing the responses, it is evident that the deployment of indirect load control is more accepted by participants than direct load control.

4.3 Recommendations

The data collected suggests that the implementation of DSM programs in Jordan may face some challenges, as stated in Figures 6 and 7. However, Figures 5 and 8 noted some scopes, such as financial incentives and reduced electricity bills, which could be focused on to increase the chances of a successful implementation of such programs.

Efforts should also be made to solve the social challenges associated with such programs, such as the lack of knowledge and trust from people, as shown in Figures 3 and 4, respectively.

Alternatively, exploring energy storage systems could present an alternative solution. Storage energy systems offer the potential to store and utilize energy more efficiently, providing a means to effectively address fluctuations in demand and supply. By considering these factors and exploring suitable approaches, it is possible to overcome barriers and effectively deploy demand-side management programs or explore alternative solutions, such as energy storage systems. One of these will be discussed in the following paragraph.

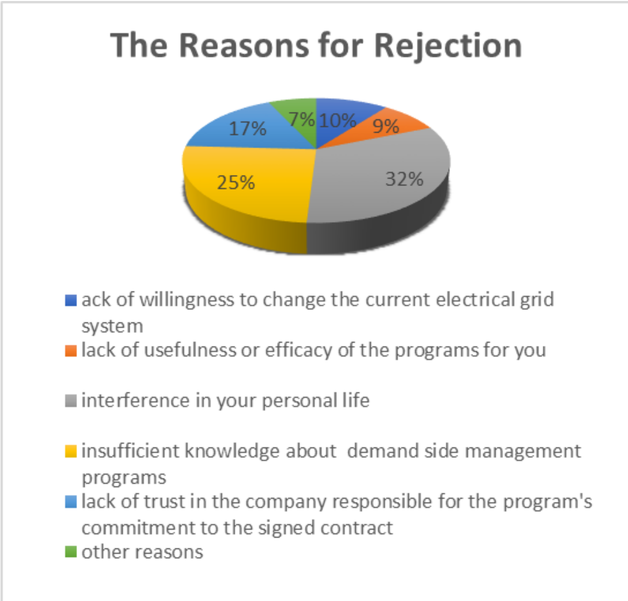

Figure-7. Reasons for rejecting direct load control.

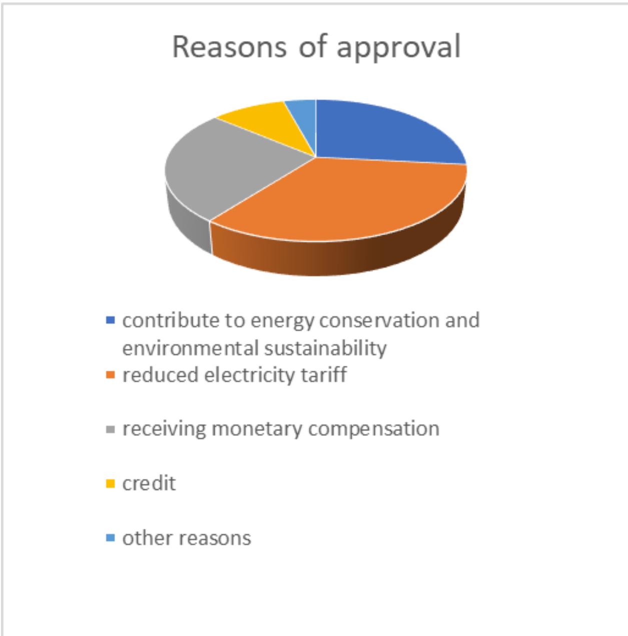

Figure-8. Reasons for approving direct load control.

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5. ENERGY STORAGE SYSTEMS

5.1 Superconducting Magnetic Energy Storage (SMES)

Superconducting Magnetic Energy Storage (SMES) is an advanced technology that enables the storage of electrical energy in the form of a direct current (DC) magnetic field within a superconducting coil. With the achievement of superconductivity, the coil experiences negligible resistance losses. However, to attain superconductivity, it is essential to operate the coil at extremely low temperatures, necessitating the use of a cooling system [38].

In Jordan, the implementation of SMES holds excellent potential for various applications, particularly in energy storage. By reducing the dependence on oil imports, SMES contribute significantly to the evolution of the energy sector.

The energy stored within a superconducting coil can be mathematically described by the following equation [39]:

$$E = \frac{1}{2} \cdot L \cdot I^2$$

Where:

E is the energy measured in Joules.
I is the current passing through L, measured in Amperes.
L is the inductance of the coil, measured in Henrys.

The formula shows that the energy saved in the coil is directly proportional to both the inductance and the square of the current passing through it.

When the electrical system requires energy stored in a superconducting coil, the coil is discharged, supplying the grid with the necessary amount of energy. [39]

The versatile characteristics of the SMES system make it suitable for addressing numerous challenges encountered in electrical networks. The table below outlines several key attributes of the SMES system, highlighting its efficacy in resolving voltage stability and power quality issues [39].

Table-4. SMES' significant characteristics.

Property / Parameter	Specific energy	Specific power	Power Density	Energy density	Self-discharge rate	Charge / discharge efficiency	Discharge time	Cycle durability	Energy Cost
Value	0.5 - 5 Wh/kg	500 2000 W/kg	1000 4000 W/L	0.2 - 2.5 Wh / L	0% at 4 K -100% at 140 K	95%	ms to 8	Unlimited cycles	$ 1000-10000 /kWh

5.2 Components of SMES

5.2.1 Superconducting coil

SMES consists of three main components: [40]

a) The superconducting coil

b) Power conditioning system

c) Cryogenic system

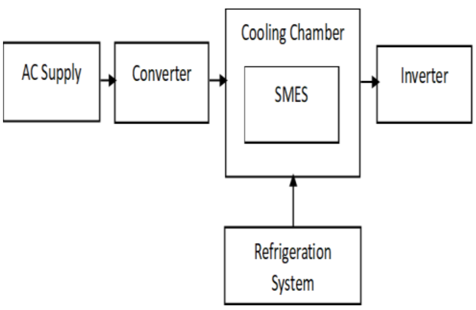

Figure-9. Schematic of SMES [40].

Superconductivity is a property of a conductor when resistance is made zero by cooling the conductor to low temperatures, allowing conductors to carry larger currents more efficiently [40]

SMES are used in many applications. For applications that fall under the medium or small scale category, the arrangement of the superconducting coil used is the Solenoid coil configuration.

When the application falls under the large scale, the arrangement of the superconducting coil used is the toroid coil configuration. [41]

One property acquired by a superconductor upon transformation into a superconducting state is the ability to conduct and carry large currents. Several materials are used to make superconducting coils, including niobium and titanium alloys. These materials can carry a current of up to 2000 A/mm^2. [40]

5.2.2 Cryogenic system

Cryogenic system is a major component of the SMES system since it is the component that cools the superconducting coil. This cooling is needed to keep the coil cool, to enable energy to be stored efficiently, since the resistive losses are then very small. [42]

A big challenge, however, is the energy needed to run the cryogenic system. Cooling down to the low temperatures necessary to make materials superconducting requires a significant amount of energy. [42]

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5.2.3 Power conditioning system

The PCS is the Mediator between the electrical network and the SMES system. The PCS includes a rectifier and an inverter. [38]

The component that changes the alternating current (AC) delivered by the electrical network into the direct current (DC) is called the rectifier. It is conducted by converting the waveform and reshaping it according to the needs of the SMES system. The rectifier is needed to make the transition of power between the electrical grid and the SMES system smooth to enable viable storage and retrieval of energy. [38]When the rectifier and inverter work together, this enables the SMES system to store excess energy and return it to the electrical grid when demand is high or the grid's stability is compromised. [38]

5.3 Types of SMES Depending on their Power Conditioning System

5.3.1 Thyristor-based SMES

It is a type of SMES system that consists of a superconducting coil, a Y-Delta transformer, and a thyristor. This type can control active power and reactive power, but not alone; its ability to maintain active power is greater than its ability to control reactive power. Therefore, it is used in applications that require controlling active power. [43]

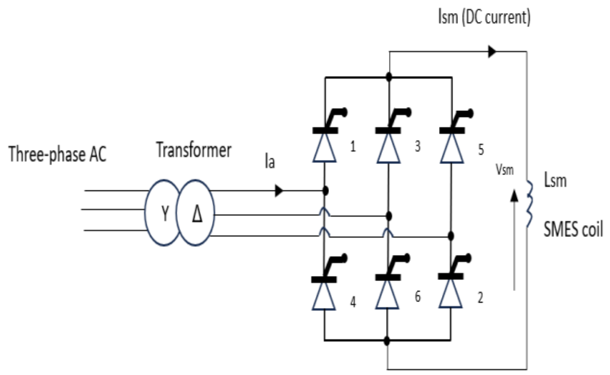

Figure-10. Basic circuit of the thyristor-based SMES. [43].

5.3.2 Voltage-source converter-based SMES

When comparing this type with the thyristor-based SMES, this system excels in its ability to independently control both active power and reactive power. [43]

A Voltage-Source Converter-based SMES system is what we get when we connect a Superconducting Magnetic Energy Storage (SMES) system to a Voltage-Source Converter. This design has the SMES unit attached to the DC side of the Voltage-Source Converter, allowing the SMES to store and dump energy as required. [43]

This SMES + a Voltage-Source Converter combination has a number of benefits. To begin with, SMES systems boast of high energy density and rapid response time, and therefore, they can absorb or deliver energy very quickly as the need may dictate. Second, the Voltage-Source Converter ensures the power flow in both directions; this enables effective energy exchange between the SMES system and the grid. [42]

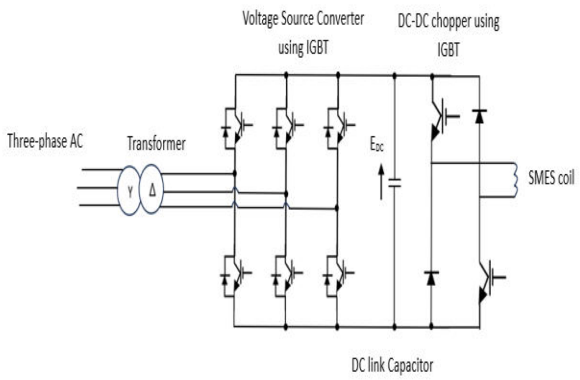

Figure-11. Basic circuit of the VSC-based SMES.

In a current-source converter-based SMES system, the CSC consists of regulating the charging and discharging of the superconducting coil. It serves as a point of interface between the power grid and the superconducting coil and controls the current being fed to the coil, and also the current being fed back by the coil. [42]

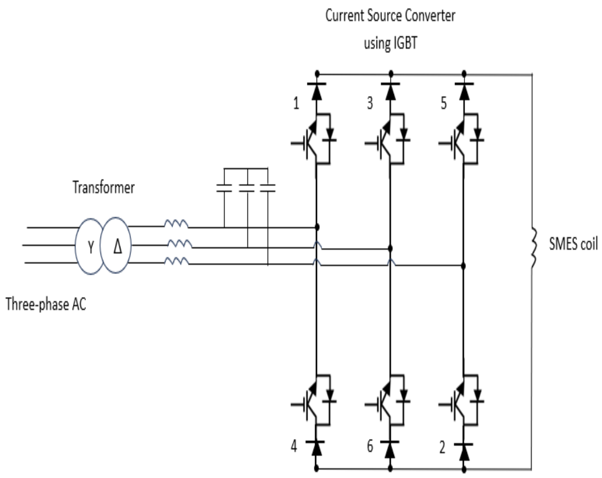

Figure-12. Basic circuit of the CSC-based SMES.

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6. CONCLUSIONS

With the increased dependence on renewable energy sources (RES) in Jordan, the challenges faced in maintaining the security and stability of the grid have intensified. Solutions developed include controlling consumers' demands through demand-side management (DSM) by actively engaging consumers in managing their electricity consumption patterns. However, this approach may face social challenges, which were examined through a survey to further understand the thoughts of Jordanian citizens on its implementation.

Technological challenges could also be faced in installing fast and reliable monitoring and communication systems.

As a result, another solution proposed that can also be used with DSM to increase the reliability of the grid further is storing excess energy generated by the SMES, which have been discussed in detail, or other types of energy storage systems such as ESS, CAES, and PHES that could be reviewed in different future studies; references to these other types (from [44] to [53]) are listed in the reference list.

With the implementation of the proposed solutions, the Jordanian electrical grid would experience reduced outages and improved voltage stability, paving the way for achieving 100% clean energy generation. Further research can be conducted on the feasibility, optimal sizing, and placement of such projects to enhance their effectiveness and efficiency.

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