RANKING OF ENERGY STORAGE FOR WIND ENERGY CORRIDOR OF NOORIABAD USING MULTI CRITERIA DECISION MAKING

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Abstract: Making decisions on energy storage requires careful consideration of a variety of technological, environmental, economic, and societal factors. Given the complexity of this decision-making process, it is essential to take into consideration a number of variables that affect the efficiency and viability of energy storage systems. In this study, a set of criteria, sub-criteria, and options relevant to energy storage in the Nooriabad wind energy corridor are successfully prioritized using the analytic hierarchy process (AHP), a systematic decision-making technique. Four overarching criteria and sixteen sub-criteria make up the assessment framework, which was created to cover the range of factors important in choosing the best energy storage option. An accurate evaluation of the various options was accomplished by a thorough investigation carried out by a panel of experts knowledgeable in specifics of energy storage systems. The Nooriabad wind energy corridor's most advantageous alternative for energy storage, according to the application of the AHP framework, is pumped hydro. This conclusion is supported by a thorough examination of the various criteria, which highlights the special benefits of pumped hydro and its compliance with the demands and features of the Nooriabad wind energy corridor. Pumped hydro is the best option for efficiently capturing and storing the intermittent energy produced by the wind turbines in the Nooriabad region due to its capacity to store large amounts of energy efficiently, along with its established reliability and relatively low operating costs.

Keywords: *Mcdm Multicriteria decision making and Ess energy storage system*

1. Introduction

Energy is a basic requirement for a nation's socioeconomic and human growth. There are two categories of energy sources: renewable and non-renewable energy sources or alternatives. While natural gas, coal, oil, and nuclear energy are classified as non-renewable energy sources, including geothermal, hydro, solar, and wind wave and biomass are considered renewable energy source. The use of fossil fuels, which are finite in supply and have serious environmental effects such as global warming and climate change, has increased exponentially as a result of population growth and technological improvements [1-3]. Therefore, scientists throughout the world are looking for new ways to cut back on or do away with the use of fossil fuels. Switching to renewable energies that are derived from the natural world and have minimal environmental impact [4]. In general, employing renewable energy is the most appealing strategy since it may greatly reduce or perhaps do away with the need for fossil fuels. According to estimates, two-thirds of the growth in renewable energy will come from renewable sources, namely solar photovoltaic and wind energy, with increases in renewable power output of around 18% and 17%, respectively [5]. However, these renewable sources are sporadic; for instance, solar panels may not function properly in cloudy weather, wind turbines may not function properly in calm weather, and renewable energy sources may occasionally provide too much electricity, overloading the system. The demand for energy storage devices (ESDs) is rising rapidly as the use of renewable energy sources rises. Every level of the network, including generation, transmission, and distribution, as well as neighborhood businesses and industries, can employ ESDs for stationary applications [6]. In order to ensure the security of the energy supply, energy storage technologies (ESTs) have been created that allow excess energy to be stored and used when it is needed [7]. Mechanical, electrical, electrochemical, chemical, and thermal energy storage alternatives and technologies (ESTs) are conceivable classifications.

1.1 Pump hydro

This system makes use of the water's potential energy and is based on two reservoirs, one upper and one lower. When the pump is in the charging position, water is pumped from the lower reservoir to the upper reservoir. In the discharge position, water flows from the higher to the lower while rotating reversible turbines produce energy.

1.2 Compressed air

The energy is stored as compressed air in an underground storage cavern using this method, which is based on standard gas turbine technology. Several high and low pressure turbines convert compressed air energy into rotational kinetic energy.

1.3Flywheel

Utilizing an electromechanical mechanism, this technology allows for the storage of kinetic energy. By accelerating the flywheel, energy is transferred to it, and when the system is discharging, the flywheel is slowed down.

1.4Super capacitor

Super capacitors which also known as ultra-capacitors bear characteristics both of batteries and capacitors and utilize an electrochemical double layer of charge in order to store electrical energy. High efficiency, high power and high cycle fatigue life are the main advantages of super capacitors

2. Literature review

2023 In the near future, renewable energy sources will be the best replacement for fossil fuels. The management of the production, use, and storage of various renewable energy sources is progressing due to the commercial production of renewable energy sources at reasonable prices.The main commercially viable renewable energy sources highlighted in this report include solar, wind, biomass, and hybrid renewable energy sources. Describe the various storage technologies and renewable energy sources [8]. 2022 Recent reviews of several research have developed and proposed various HESSs for various applications, demonstrating the significant advantages of combining multiple ESSs into a single integrated system. Thus, this study is to investigate and assess the significance and influence of HESS in the presence of renewable energy on sustainable development as a novel contribution to the literature. This will help academics in the area better understand this developing topic [9]. 2021 For us to use energy produced by erratic renewable sources like wind and solar when and where we want, renewable hydrogen generation is a terrific way to store and transfer it. Using a number of multi-criteria decision-making tools, such as ARAS, SAW, CODAS, and TOPSIS, the suitability of 15 cities in the Iranian province of Fars for the generation of renewable hydrogen was studied and compared in this study. Based on the results of multi-criteria decision-making approaches, Izadkhast was found to be the most beneficial location for the research area's production of renewable hydrogen [10]. 2020 Choosing an appropriate phase change material (PCM) for thermal energy storage from those that are available depends on the application. From the commercially available PCM, a specific PCM is to select the optimum material for a given situation. The problem of selecting a material for various applications can be solved by using a method to choose amongst five PCM for solar heating systems while taking into account both the technical requirements and the material's criteria. Materials from the chosen PCM are utilized for this solar heating system using the AHP technique [11]. 2019 A bank energy storage system (BESS) eliminates the unfavourable aspects of instability and erratic power supply for renewable energy sources, especially wind power, levelling production control variations for micro-grids. The operating costs of the Wind-ESS system are significantly impacted by the reduction in battery size [12].

2017 Due to the complexity of social, technological, and economic issues, this work must consider a number of factors. In order to enhance decision-making, article uses the analytical hierarchy process (AHP) to rank a set of criteria, sub-criteria, and alternatives. With a 45.3% share, solar energy was the greatest renewable energy option.2017Evaluation of energy storage alternatives, or technologies, is therefore very necessary and precisely qualifies as a multi-criteria decision making (MCDM) problem. This work proposes an integrated MCDM model to assess EST alternatives for Turkey in a hesitant fuzzy environment. The model comprises of Delphi, Analytic Hierarchy Process (AHP), and VIsekriterijumska Optimizcija I Kompromisno Resenje (VIKOR) methodologies [13]. 2017 Due to the complexity of social, technological, and economic issues, this work must consider a number of factors. In order to enhance decision-making, article uses the analytical hierarchy process (AHP) to rank a set of criteria, sub-criteria, and alternatives. With a 45.3% share, solar energy was the greatest renewable energy option [14].

3. Methodology

The Analytic Hierarchy Process (AHP) is used in this scenario to choose the best Energy storage system for wind energy corridor of Nooriabad. AHP is a mathematical analytical tool for MCDM problems that is based on a concept of relative measurement [15]. As a result of its logical and methodical approaches to problem-solving, it is one of the most used MCDM techniques [16]. AHP approaches multi-alternative, complex, and unstructured decision-making situations by creating a hierarchy for the choice [16]. Instead of a precise numerical score, the relative evaluation of alternatives is used to determine which option is best [15]. The capability of AHP to evaluate intangibles in a clear and structured manner is one of its benefits [23]. AHP has been applied in a variety of domains by researchers from many nations, including the selection and evaluation of renewable energy sources and technologies [17]–[18]. The steps for performing an AHP are as follows.

Having a set of criteria C and a finite set of alternatives X,

$$C = \{C1, C2 \,.\,.\,.\,.\,.\, Cn\} \quad (1)$$

$$X = \{x1 ,x2 \,.\,.\,.\,.\,.\, xn\} \quad (2)$$

By breaking the issue down into a hierarchy comprising the aim (top level), criteria (mid-level), and options (lowest level), a model for the choice is created. By applying Saaty's pairwise comparison scale, criteria are compared pairwise with respect to the needed aim to determine priorities (weights) for each criterion [22]. A square matrix is created from the pairwise comparisons that are made.

$$A = \begin{bmatrix} a_{11} & a_{22} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (3)$$

The criterion in the ith row is better than criterion in the jth column if the value of clement (i, J) is more than I Consistency test is performed by evaluating the consistency of the matrix A to check if there are any errors in judgments. The consistency index, CI, is given a

$$CI = (\lambda_{max} - n)/(n-1) \quad (4)$$

where A is the highest eigenvalue of the matrix A and n is the number of criteria for each level.
As follows is the consistency ratio:

$$CR=CI/RI \quad (5)$$

where the random index is R l. R l values are provided in [26]. If CR is less than 0.1, matrix A should be consistent. The pairwise comparisons must be examined again and modified if there is any contradiction.

Similar to the previous phase, pairwise comparisons their advantages. A and n is the number of criteria for each level.

3.1 Using AHP for selecting Energy storage system

Software called Super Decisions is used to create and evaluate decision models. Both the Analytic Hierarchy Process and the Analytic Network Process are implemented by it. By organizing the issue into a three-level hierarchy, a model is created. The goal, which is the choice of energy storage technologies, is at the top of the hierarchical structure. The criteria are on the second level, while the options are on the third level. As listed in Table I, there are four selection criteria.

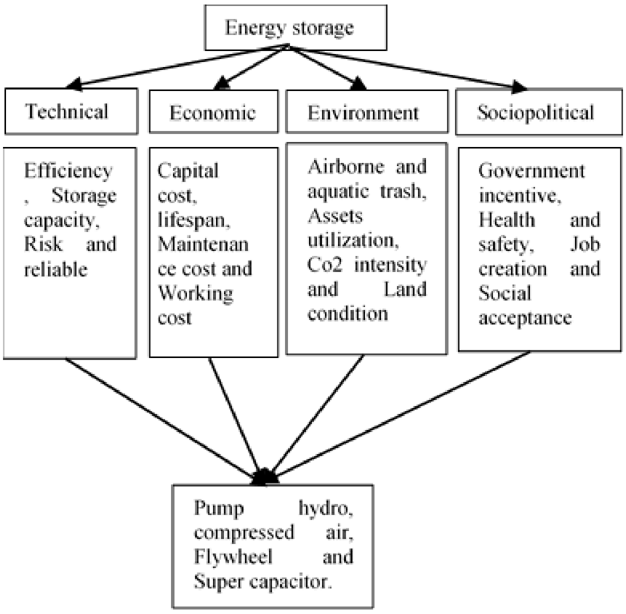


Fig 1: The proposed model

3.1.1 Weight of Main criteria

$$\begin{bmatrix} \text{Technical} \\ \text{Economic} \\ \text{Environment} \\ \text{Sociopolitical} \end{bmatrix} = \begin{bmatrix} 0.17401 \\ 0.10348 \\ 0.67103 \\ 0.05149 \end{bmatrix} \quad (6)$$

3.1.2 Weight of Alternative

$$\begin{bmatrix} \text{Pumped Hydro} \\ \text{Flywheel} \\ \text{Compressed air} \\ \text{Supercapacitor} \end{bmatrix} = \begin{bmatrix} .58304 \\ .17628 \\ .08720 \\ .15348 \end{bmatrix} \quad (7)$$

3.1.3 Final Rankings of Alternatives w.r.t. Goal.

Figure shows the final ranking of alternatives with respect to the goal. In this particular situation, the overall inconsistency is 0.05. The final ranking indicates, that the best alternative is alternative 3 Pumped hydro with a percentage of 58.3%. Alternative 3 Flywheel comes in second with a share of 17.6%. Alternative `Super capacitor, which has a proportion of 15.3%, is in third position. Alternative 4 Compressed air comes in forth with a share of .087% as show in fig.

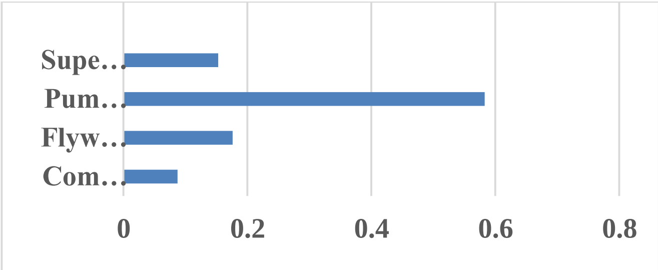


Fig:2 Final Rankings of alternative with respect to goal

4.1. Limitation of wind energy

4.1 Intermittency

Is a key restriction on wind energy. When the wind blows within a specified range of speeds, wind turbines produce power. However, because wind patterns change throughout the day and across the seasons, energy output is variable. Wind turbines may only produce little to no power during calm periods or when the wind is too little, making it difficult to maintain a continuous energy supply. Batteries are a common energy storage device used to store extra energy during windy conditions and release it during calmer conditions [19].

4.2 Geography dependency

Another important restriction is e. In areas with continuous and powerful winds, wind energy is the most economically viable option. Not every site fits these requirements, and the ideal places for wind farms could be remote from inhabited areas. This calls for the installation of several transmission lines, which raises the cost and might have an adverse effect on the environment.

4.3. Environmental and aesthetic concern

Are important restrictions. Large-scale wind farms may change the scenery and have unsightly effects, according to some. Additionally, because of the possibility of contact with whirling blades, wind turbines can endanger species, especially birds and bats. To lessen these consequences, careful site selection and environmental studies are necessary.

4.4. High Start -up cost

continue to prevent widespread use of wind energy. Even though wind energy has become more affordable over time, constructing wind farms still needs a sizable upfront investment. Potential investors may be discouraged as a result, necessitating the need for favorable legislation and financial incentives to make wind energy projects profitable [20].

4.5. Grid challenge integration

Emerge from how irregular and varied wind resources are. It is frequently important to adopt energy storage systems and enhance the electrical grid infrastructure in order to guarantee a steady and dependable energy supply.

4.6. Low wind speed

Low wind speeds are common in several areas of Pakistan during particular seasons. In order for wind turbines to produce power effectively, there must be a minimum wind speed. The capacity factors of wind farms are restricted by insufficient wind speeds, which lowers overall energy production.

4.7. Maintenance and reliability

concerns are also important. Wind turbines require regular maintenance to operate at their best and have a long lifespan. However, maintaining turbines, especially those located offshore or in remote areas, can be costly and logistically challenging, affecting their overall reliability [21].

4.8. Wind turbine technology

To maximize energy output, the technology of the wind turbine must be carefully considered. It may be difficult to efficiently utilize the available wind resources with outdated or inefficient turbine designs. Modern, more efficient turbine designs can help to get over this restriction.

4.9. Energy storage

Due of wind energy's unpredictability, devices for storing surplus power produced during windy conditions are required. When there is a surge in demand or when there is little wind, these energy reserves can then be released. For the supply and demand to be balanced, effective and economical energy storage techniques must be used.

4.10. Transmission facilities

Pakistan may have viable wind energy locations that are positioned distant from significant load centers. To get power from these outlying facilities to places where it is required effectively, a sizable transmission system must be built. However, building and maintaining this infrastructure may be costly and logistically difficult.

4.11. Power quality and grid

Power quality and grid stability may be impacted by wind power's fluctuation. Smart grid solutions and cutting-edge grid technology must be used to ensure a dependable power supply, allowing the system to properly handle changes in power production. It is essential for Pakistan to address these technical constraints via technological development, strategic planning, investment in infrastructure and research in order to fully realize the promise of wind energy and establish it as a reliable and sustainable source of electricity for the country.

5.Key Strategies for Overcoming Limitation in Pakistan

A variety of tactics may be used to get over technical obstacles and improve Pakistan's wind energy potential. These strategies seek to increase the grid integration, dependability overall, and efficacy of wind power generation. Here is a list of the principal remedies.

5.1 Utilizing wind advanced turbine

Invest in and put into use cutting-edge wind turbine technology that can function effectively even in winds as low as 20 mph. These modern turbines can extract more energy from a variety of wind resources because to their greater rotor diameters and enhanced aerodynamics.

5.2 Implementing energy storage system

Utilize techniques for energy storage, such as batteries, pumped hydro storage, or compressed air energy storage, to store extra electricity produced during high wind events. This energy can be released during periods of high demand or low wind, maintaining a steady supply of electricity [22].

5.3 Upgrading and managing Grid

Improve the architecture of the electric grid to handle higher amounts of sporadic wind power. Demand-response systems and real-time monitoring are two advanced grid management strategies that can assist balance supply and demand while enhancing the grid's stability.

5.4 Developing hybrid Power System

By integrating wind energy with other renewable energies like solar electricity, hybrid power systems may be created. Combining several renewable energy sources reduces their intermittency and creates a more dependable and steady power supply.

5.5 Implementing micro grid

Introduce micro grid systems in off-the-grid or isolated locations with wind energy potential. With the help of micro grids, localized energy distribution is possible while less extensive transmission infrastructure is required. They can run alongside the primary grid or independently of it.

5.6 Strategic site selection and plaining

To determine the best locations for wind farms, do thorough site evaluations and wind resource analyses factors such wind direction, speed, and Weather patterns should be taken into account to maximize energy output while reducing negative effects on the environment and escalating tensions in the community.

5.7Building and maintaining capacity

Invest in courses that help wind energy engineers and technicians enhance their capacities. This guarantees that experienced employees are used for wind turbine installation, operation, and maintenance, increasing overall efficiency and lifetime.

5.8 Fostering research and development

Encourage innovation and study in the field of wind energy to provide solutions suited to Pakistan's unique requirements. Technologies that have been regionally tailored can take care of the country's particular needs.

6 Sensitivity analysis with respect to goal

The energy storage is not highly sensitive to substitutes when it is increased from 0% to 25%. Put the hydro pump first. Flywheel is ranked number two, super capacitor is ranked number three, and compressed air is ranked number four as shown in fig 3.

It is found that the ranking of alternatives is not significantly affected by the economic criterion. When the economic criterion's weight is increased from its starting value of 10% to 25%, as indicated in fig. 5, only Option 2 (58% Pump hydro) succeeds as shown in fig 4.

Fig. 5 Shows how sensitive the ranking of options is with respect to environmental factors. The environmental criterion's weight is reduced from 67% to 25% without affecting the choices' ranking. The alternatives remain in the same sequence. Pumped hydro is currently the best alternative.

As the socio-political weight is raised from 5% to 25%, alternative 3 (18% Flywheel) is now the second-best choice, after alternative 2 (58% Pumped hydro), according to the sensitivity analysis of alternative rankings in relation to socio-political factors (Fig. 6).

When the technical criteria's weight is increased from 17% to 25%. The ranks of alternatives stay the same by increasing the weight of the technical criterion. First, pumped hydro, the second alternative, is chosen as shown in fig 7.

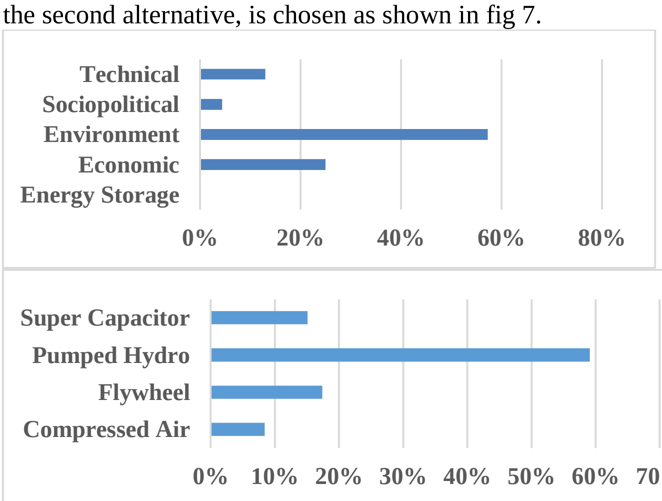


Fig:3 Shows the impact of 25% increase in energy storage on Pump hydro, compressed air, flywheel and Super capacitor

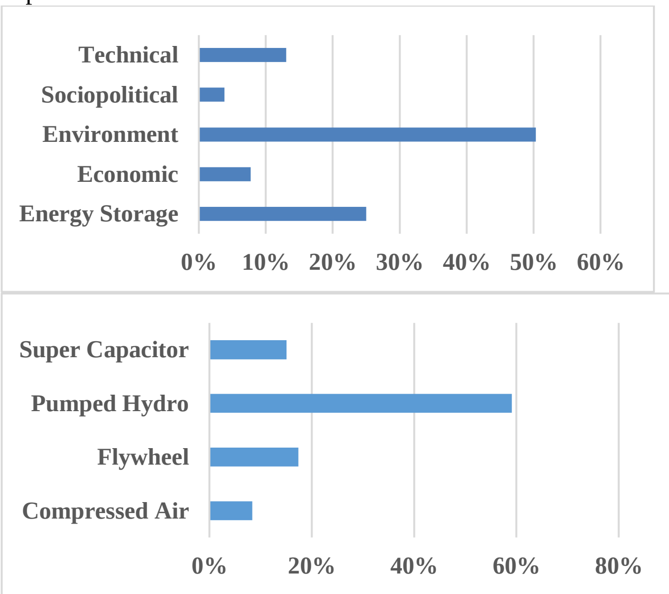


Fig:4 Shows the impact of 25% increase in economic on Pump hydro , compressed air , Flywheel and Supercapacitor

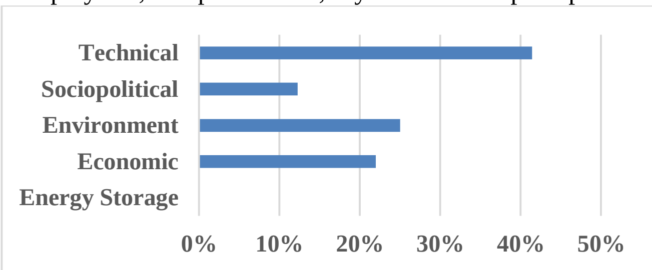
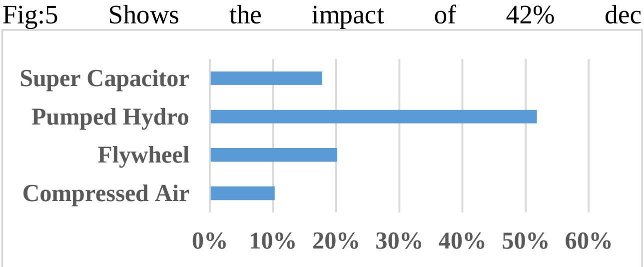


Fig:5 Shows the impact of 42% dec



rease in environment on Pump hydro , compressed air , Flywheel and Supercapacitor

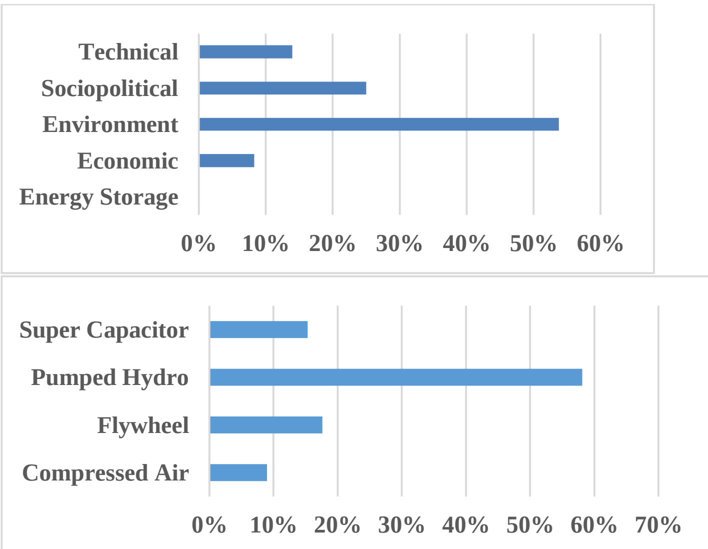


Fig:6 Shows the impact of 25% increase in socio political Pump hydro , compressed air , Flywheel and Supercapacitor

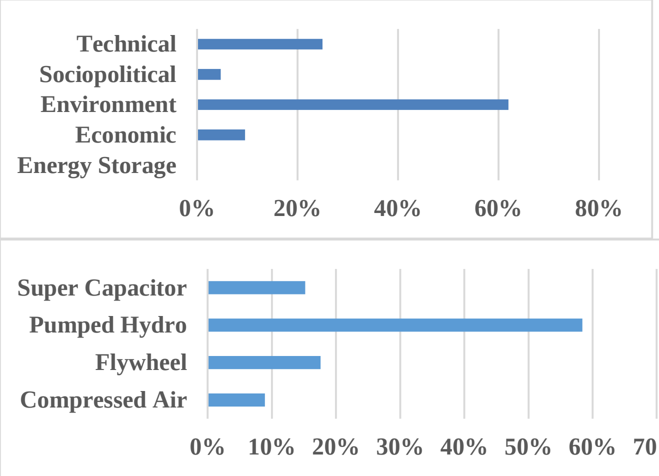


Fig:7 Shows the impact of 25% increase in technical on Pump hydro , compressed air , Flywheel and Supercapacitor

7 Conclusion

In order to choose the appropriate energy storage option, it is important to take into account a broad range of elements, including technological, environmental, economic, and socio-political considerations. The results of this study clearly support pumped hydro as the most advantageous kind of energy storage for the Nooriabad wind energy corridor. Together with its proven dependability and relatively cheap operating costs, its capacity to efficiently store vast amounts of energy fits in well with the region's special features. A viable method for capturing and storing the sporadic energy produced by wind turbines is pumped hydro, which would provide a steady and reliable supply of electricity.

References

[1]. Makieła, K.; Mazur, B.; Głowacki, J. The Impact of Renewable Energy Supply on Economic Growth and Productivity. Energies2022,15,4808

[2]. 2. Khezri, M.; Karimi, M.S.; Mamkhezri, J.; Ghazal, R.; Blank, L. Assessing the Impact of Selected Determinants on Renewable Energy Sources in the Electricity Mix: The Case of ASEAN Countries. Energies 2022, 15, 4604.

[3]. 3 . Zhu, Y.; Huo, C. The Impact of Agricultural Production Efficiency on Agricultural Carbon Emissions in China. Energies 2022, 15,4464

[4]. 4 Roosjen, S.; Glushenkov, M.; Kronberg, A.; Kersten, S. Waste Heat Recovery Systems with Isobaric Expansion Technology Using Pure and Mixed Working Fluids. Energies 2022, 15, 5265.

[5]. 5 . IEA 2021. Global energy review

[6]. 6. BNEF, New Energy Outlook. Avaliable online: https://www.power-technology.co m/news/bloomberg-new-energy-outlook-2019-2/. [Accessed 11 April 2021].

[7]. 7. M .Colak, I kaya, Prioritization of renewable energy alternative by using an integrated fuzzy mcdm model, a real case study for turkey

[8]. 8. Olabi, A. G. "Renewable energy and energy storage systems." *Energy* 136 (2017): 1-6.

[9]. 9. Li, Nan, et al. "How to select the optimal electrochemical energy storage planning program? A hybrid MCDM method." *Energies* 13.4 (2020): 931.

[10]. Amer, A. E., K. Rahmani, and V. A. Lebedev. "Using the Analytic Hierarchy Process (AHP) method for selection of phase change materials for solar energy storage applications." Journal of Physics: Conference Series. Vol. 1614. No. 1. IOP Publishing, 2020.

[11]. .Pang, N., Meng, Q., & Nan, M. (2021). Multi-Criteria Evaluation and Selection of Renewable Energy Battery Energy Storage System-A Case Study of Tibet, China. IEEE Access, 9, 119857-119870.

[12]. Çolak, M., & Kaya, İ. (2020). Multi-criteria evaluation of energy storage technologies based on hesitant fuzzy information: A case study for Turkey. Journal of Energy Storage, 28, 101211.

[13]. Algarín, Carlos Robles, Aura Polo Llanos, and Adalberto Ospino Castro. "An analytic hierarchy process based approach for evaluating renewable energy sources." International Journal of Energy Economics and Policy 7.4 (2017): 38-47.

[14]. Dunmade, "Indicators of sustainability : assessing the suitability of a foreign technology for a developing economy," Technol. Soc., vol 24, pp. 461-471, 2002.

[15]. E. C. X. Ilrejemba, P. B. Mpuan. P. C. Schuur, and J. Van Hillegersbe!J!, "The empirical reality & sustainable management failures of renewable energy projects in Sub-Saharan Africa (part 1 of 2)," Renew. Energy, vol. 102, pp. 234-240, 2017

[16]. S. H. E. A. Aleem, A. Y: Alxlelllzlz, A. F. Zobaa, and R. B=al, Eds., Decision Making Applications in Modem Power Sy&terns. Academic Press, 2020.

[17]. E. Mu and M. Pereyra-Rojas, Practical Decision Maldng using Super Decisions v3: An Introduction to The Analytic Hierarchy Process. Springer, 2018.

[18]. Ahmed, S. D., Al-Ismail, F. S., Shafiullah, M., Al-Sulaiman, F. A., & El-Amin, I.M. (2020). Grid integration challenges of wind energy: A review. IEEE Access, 8, 10857-10878

[19]. Baumann, M., Weil, M., Peters, J. F., Chibeles-Martins, N., & Moniz, A. B. (2019). A review of multi-criteria decision making approaches for evaluating energy storage systems for grid applications. Renewable and Sustainable Energy Reviews, 107, 516- 534.

[20]. Wu, Y., Xu, C., Zhang, B., Tao, Y., Li, X., Chu, H., & Liu, F. (2019). Sustainability performance assessment of wind power coupling hydrogen storage projects using a hybrid evaluation technique based on interval type-2 fuzzy set. Energy, 179, 1176- 1190.

[21]. Xu, F., Liu, J., Lin, S., Dai, Q., & Li, C. (2018). A multi-objective optimization model of hybrid energy storage system for non-grid-connected wind power: A case study in China. Energy, 163, 585-603.