Brilliance
Research of Artificial Intelligence

**Volume** 3, **Number** 1, May 2023
https://doi.org/10.47709/brilliance.v3i1.1941

# A Role of Mechanical Energy Storage Systems in Grid Application

**Muftah Emtir Ali**[1*]
[1] Department of Electrical and Electronic Engineering, Karabuk University, Karabuk, Turkey.
[1] muftahali2016@gmail.com,

open access

***Corresponding Author**

**Article History:**
Submitted: 17-12-2022
Accepted: 05-01-2023
**Published: 09-01-2023**

**Keywords**
MESS; POWER QUALITY; GRID; APLICATION;



**ABSTRACT**

Mechanical Energy Storage Systems (MESS) technologies are still posing complex threats to power grids. The MESS model is designed to offer a highly flexible center to electrical power that is involved in combining energy resources and request loads to industrial influence, safe high-voltage equipment, and produce high-quality power. Furthermore, electricity grids can have started to utilize all of the advantages of a potent mix of decentralized resources for renewable energy. This article's impact is to adopt modern MESS innovations that are combined with improved efficiency, energy efficiency, and fast reaction to incorporate electricity systems. As a consequence, the primary purpose of this article is to present a critical review of the major innovations in MESS that are especially suited to the evolution of the electricity network and its capabilities.

## INTRODUCTION

In today's world, energy plays an important role in sustaining the economy's stable [1]. To demonstrate this point, energy demand is expected to fall across the country in 2020. In Asia, it was assumed that energy consumption would fall by around 4%, rolling back the estimated yearly growing demands of about 3% in both 2010 as well as 2019. For the very first period in 2019, India's electricity consumption has greatly reduced. Notwithstanding this, emerging economies will see the greatest reduction in energy supply in 2020. The requirement in the United States (US) and the European Union is expected to decline by 10% in 2020 compared to 2019 levels, doubling the global effect. This can be seen, the Covid-19 crisis has an impact both economically and environmentally on global energy consumption. Fig. 1, illustrates the rise in energy consumption by country in 2019-2020. Renewable energy resources (RER) are evolving into a crucial component of today's high-voltage grids' energy continuity [2]. Obviously, RERs are infrequent and unreliable. ESS technologies are available to address these issues, and their rapid integration is required to mitigate the negative effects of global warming. From this vantage point. Renewable energy is generating more power supply than the preceding year.

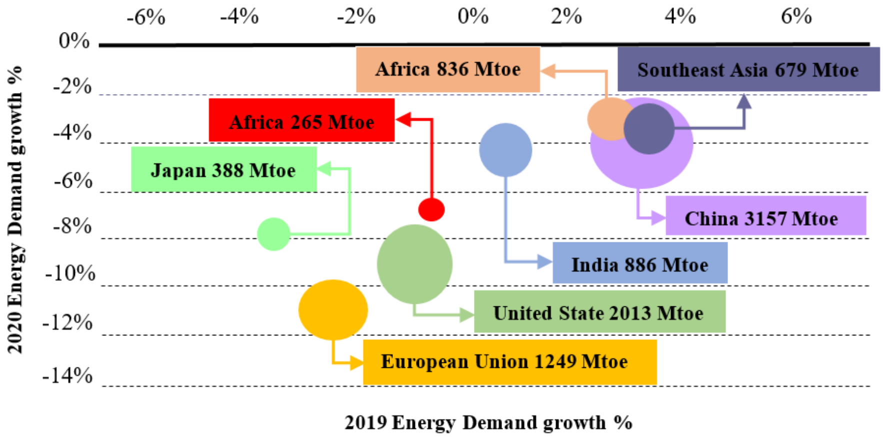


Fig. 1. The growth of energy demand by countries in 2019-2020 [2].

Regrettably, storage capacity fell by nearly 30 percentage points in 2019 as 2.9 GW has been added to world energy systems. Since the review year and in 2018, because once Korea implemented one-third of the world's potential, yearly setups in Korea ended up falling by 80%. A few huge storage fires at power station plants contributed to the drop

**Volume** 3, **Number** 1, May 2023
https://doi.org/10.47709/brilliance.v3i1.1941

in 2018. Furthermore, India has expressly compensated for this implementation by proposing 1.2GW of solar-plus-storage auction sites in 2019, going to require storage implementation for 50% of installed capacity. Singapore might have established a goal of 200 MW of storage capacity for 2025. Besides that, the implementation of ESS software has resulted in a fast reply, friendly, and excellent service to settle electrical grid interconnect issues for renewable energy sources. Fig. 2, shows ESS that can be categorized by the type of energy they store [3].

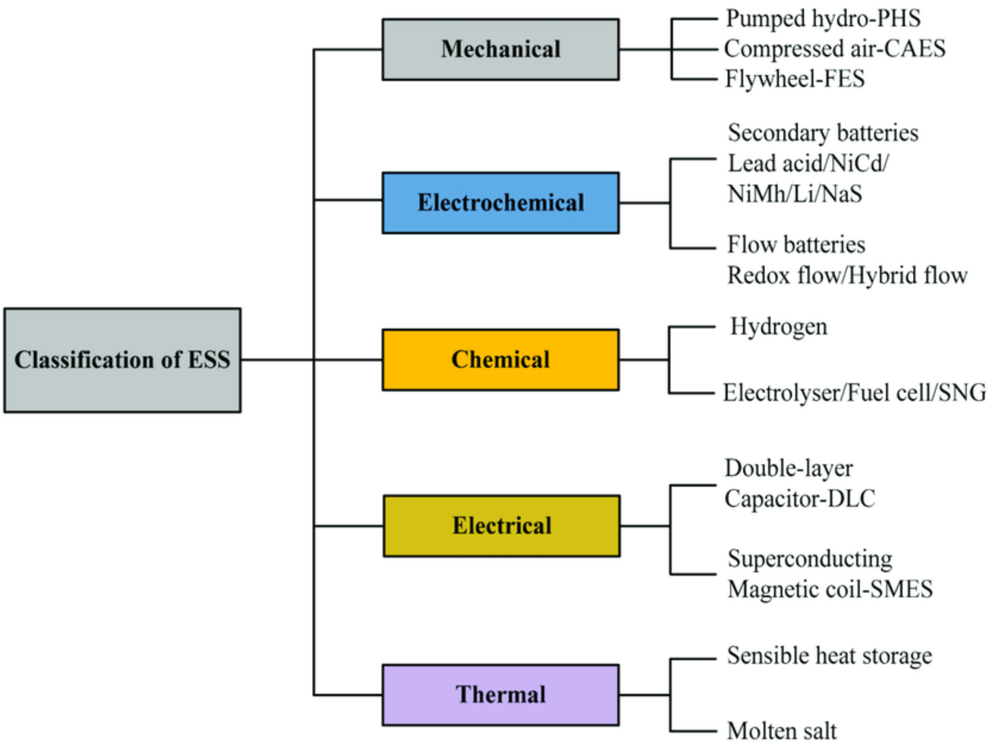


Fig. 2. The ESS is categorized by the type of energy they store [3]

## LITERATURE REVIEW

The power industry has gone through unparalleled shift patterns and continues to face multiple difficulties with power grid performance indicators. Overarching power system financial support in power grids started falling for the third consecutive year in 2019, falling 7% from the 2018 stage to less than USD 275 billion. With changeable renewable sources and the supply of electricity being more and more important in Europe, assets in improving and renovating existing power stations have held steady at approximately USD 50 billion. Growing power supply and serviceability have led to rapid grid expansion, making the conventional energy scheme more difficult to manage and operate consistently [3]. According to the REN21 article, hydroelectric power even now represented nearly 60% of clean energy electricity production in 2018, accompanied by wind (21%), solar PV (9%), and bio-power (8%). Going to assume that by the end of the year, the capacity for renewable energy could supply approximately 26.2% of electricity in the world. Fig. 3, depicts the worldwide electric generation share based on renewable energy for the end of 2018 [4].

Brilliance
Research of Artificial Intelligence

**Volume** 3, **Number** 1, May 2023
https://doi.org/10.47709/brilliance.v3i1.1941

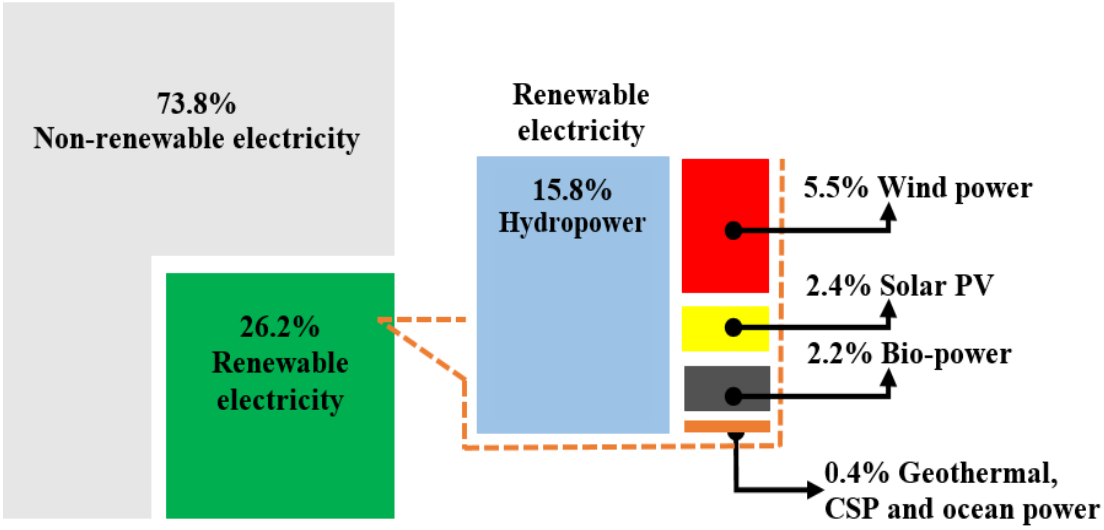


Fig. 3. The global electricity production share estimated for end-2018 based on renewable energy [2]

The International Energy Agency (IEA) released a report in 2018 stating that the global overall energy demand was 14282 Mtoe, with 13.5% coming from renewable sources such as hydro, bio-fuels, renewable municipal solid waste, solar PV, solar thermal, wind, geothermal, and tidal. The renewable energy sector has shown tremendous ability to adapt in the face of the Covid crisis, the U.s reached 80.0 GW [5]. The European Union has enhanced 5.0 GW of the United States from 2019 to 2021. China 2019-2021 has maintained the top value by 233.0 GW. The contribution from India for 2019-2021 is 37.0 GW. Finally, other countries from 2019 to 2021 total of 608.0. Table 1, shows the renewable energy capacity additions by region from 2019-2021.

Table 1. Renewable energy capacity additions by region from 2019-2021.

| Region | 2019 | 2020 | 2021 |
|---|---|---|---|
| United States | 22.0 GW | 29.0 GW | 29.0 GW |
| European Union | 27.0 GW | 26.0 GW | 32.0 GW |
| China | 66.0 GW | 85.0 GW | 82.0 GW |
| India | 12.0 GW | 9.0 GW | 16.0 GW |
| Other countries | 64.0 GW | 49.0 GW | 60.0 GW |
| | Total = 191.0 GW | Total = 198.0 GW | Total = 219 GW |

The remaining stages of the research have been described. Section 2 is essential to the discussion of the various types of MESS innovations. Section 3 demonstrates MESS application areas in a power grid. Section 4 contains the study's findings.

## METHOD

The various kinds of MESS are divided into categories based on their primary operation to evaluate the context of the subsequent subsections. As a result, the MESS technology types in electrical grids are outside the scope of this paper. Fig. 4 depicts Compressed-Air Energy Storage (CAES), Pumped Hydro (PH-ESS), and Flywheel Energy Storage System (F-ESS) technologies. CAES is also classified according to their idealized change of state (D (diabatic), A (adiabatic), and I (isothermal)-CAES) [6].

**Volume** 3, **Number** 1, May 2023
https://doi.org/10.47709/brilliance.v3i1.1941

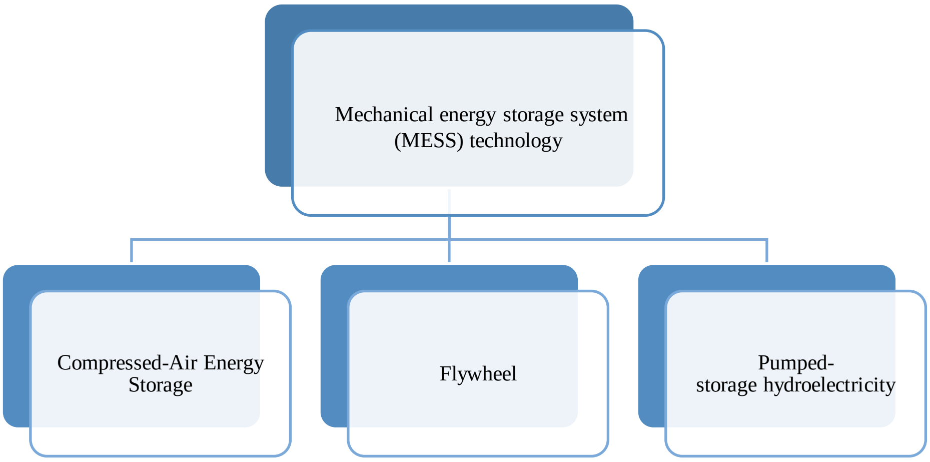


Fig. 4. Mechanical energy storage system (M-ESS) technology.

The fundamental principles of storing energy using compressed air were established during the 1940s. F.W. Gay has forwarded a finished work captioned Means for Storing Fluids for Energy Production. By that moment, F.W. Gay had been granted a patent for his invention from the US Patent Office [7]. The two main CAES plants have been functioning for decades in the United States and Germany. These plants have power generation capabilities of 110.0 MW and 321.0 MW. Germany took the lead in improving the CAES factory in a specific region till the late 1960s. Take full advantage of the huge potential deep inside the earth's domes to achieve this goal anywhere and everywhere possible. The research study was performed on two major problems: (i) raise the respondents confirmed for CAES operating requirements. (ii) The viability of second-generation CAES, also known as adiabatic CAES (A-CAES), aimed at reducing the use of petroleum fuels for firing. Moreover, Diabatic D-CAES, adiabatic A-CAES, and isothermal I-CAES are the three types of CAES as shown in Fig. 5.

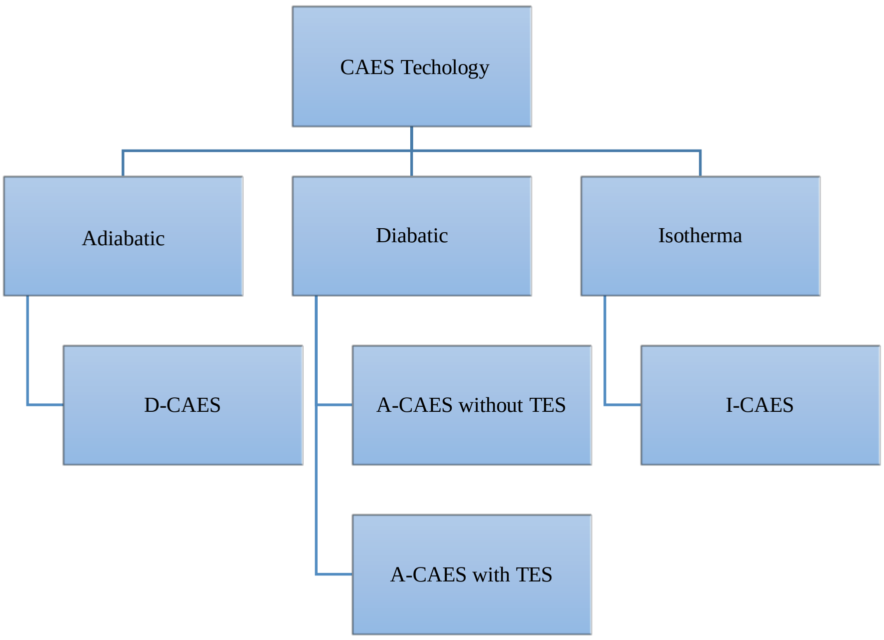


Fig. 5. Compressed air energy storage concepts are classified by their idealized change of state: D (diabatic), A (adiabatic), I (isothermal)-CAES).

Brilliance Research of Artificial Intelligence

**Volume** 3, **Number** 1, May 2023
https://doi.org/10.47709/brilliance.v3i1.1941

Six new CAES developments are currently being processed in China in 2019. Whilst also Australia has formally announced its intention to construct four new 1.5 GW pumped hydro investments. United Kingdom (UK) proclaimed that gravitational attraction storage was able to obtain direct exposure to a GBP 1 million 4 MW protest plant. Regardless of the fact that the United Kingdom has been a leader in gravity storage. The Electricity Research Institute funded a research group, which ultimately led to diabatic CAES being deemed as a short-term technology for energy storage. Fig. 6, depicts CAES operational requirements [8].

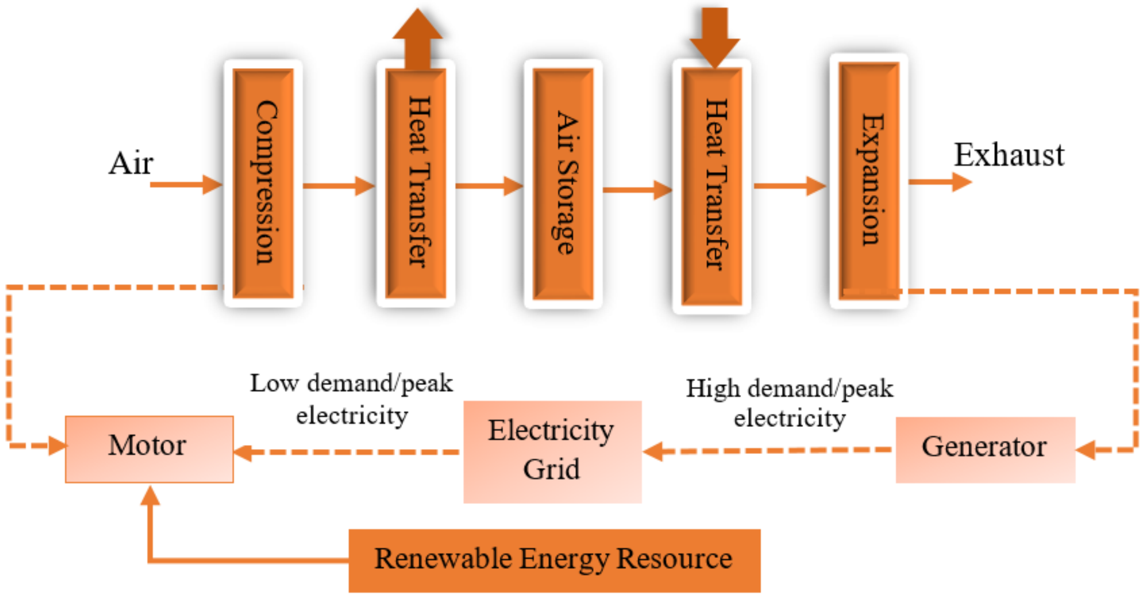


Fig. 6. Operational level of CAES

As a direct consequence, the Electric Power Research Institute in the United States assumes full responsibility for improving second gen CAES including adiabatic, isothermal CAES (I-CAES), and hybrid. Fig. 7, illustrates the structure of an isothermal CAES system intergraded with a wind turbine [9]. The Pacific Northwest National Laboratory (USA) is seriously contemplating A-CAES as a promising technology that is particularly well-suited for a wide range of applications. Whereas the Electric Power Research Institute wants to consider hybrid CAES plants with thermal energy storage systems (T-ESS) to be the most hopeful second-generation solution (EPRI). CAES at 400.00 MW is the source of grid-scale storage of electricity.

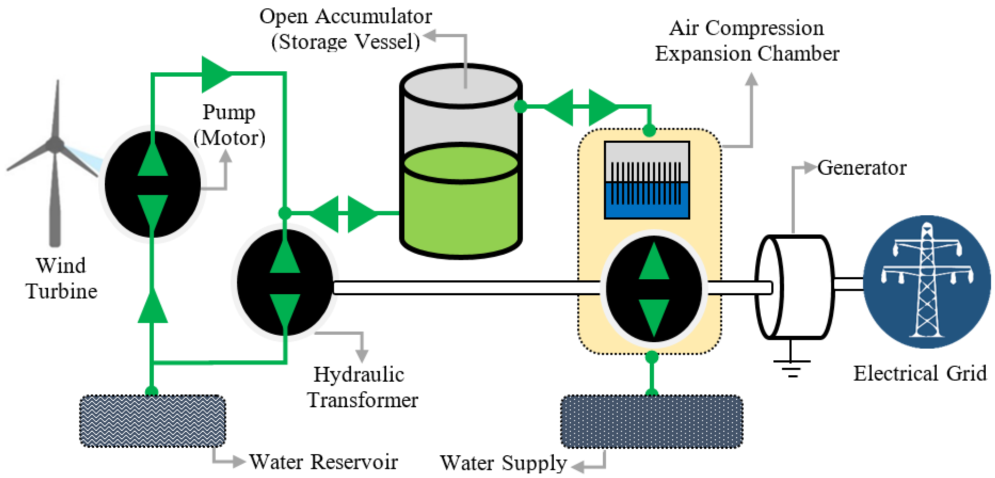


Fig. 7. The system architecture of isothermal CAES of integrated with a wind turbine

F-ESS has rapidly gained traction in electrical grids. One practical advantage of the F-ESS is that it can address the growing issue of power quality (PQ) in electrical grids [10]. The flywheel, a key component of ESS, is a turntable

**Volume** 3, **Number** 1, May 2023
https://doi.org/10.47709/brilliance.v3i1.1941

disk used as a mechanical energy storage tool. Composites have recently been found to be more supportive of efforts to increase the rotational stress threshold and speeds of F-ESS than steel. Fig. 8, conveys a fast F-ESS that can store the amount of electricity as kinetic energy all across the rotating mass.

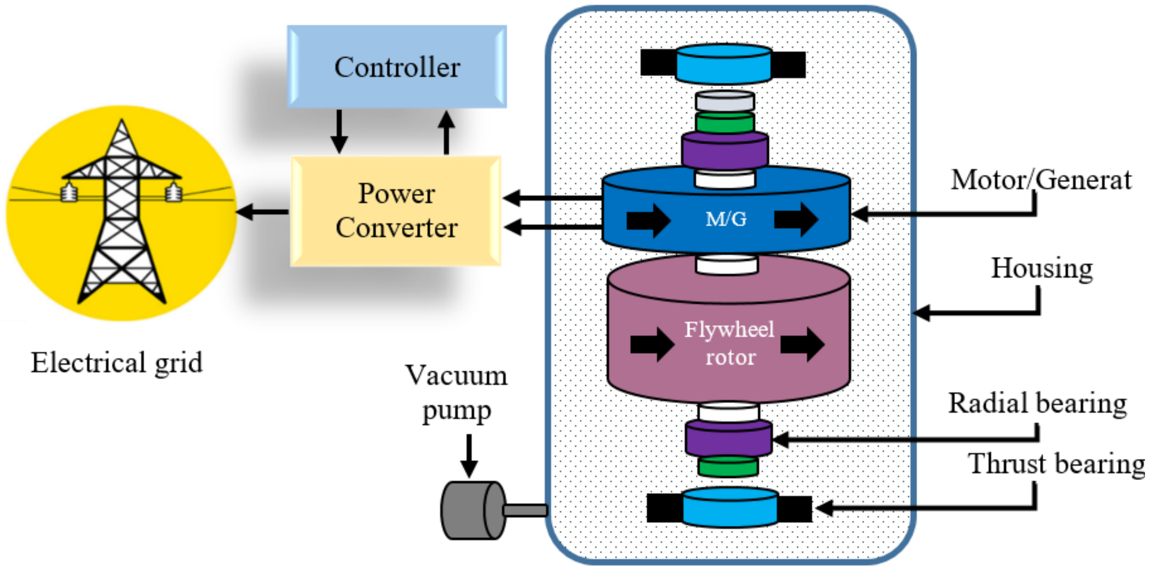


Fig. 8. High speed of F-ESS

Fig. 8, highlights the most critical mechanical part of F-ESS, which is the bearing. The overall bearings of the F-ESS are divided into two types: (i) mechanical bearings and (ii) magnetic bearings. Mechanical bearings have been successfully applied for low-speed F-ESS. These mechanical bearings can have their drawbacks by friction and require lubrication and maintenance. More particularly, the variable reluctant machine (VRM), the induction machine (IM), and the permanent magnet machine (PMM) are utilized by F-ESS [11]. Table 2, discusses in detail the suitable F-ESS for the power grids.

Table 2. The suitable F-ESS for the power grids.

| F-ESS | Asynchronous | VRM | PMM |
|---|---|---|---|
| power | High | Medium | Medium |
| Spinning losses | Removable by annulling flux | Removable by annulling flux | Non-removable, static flux |
| Efficiency | High | High | Very high |
| Control | Vector control | Synchronous: Vector Control. Switched: DSP | Sinusoidal: Vector control. Trapezoidal: DSP |
| Size | 1.8 L/kW | 2.6 L/kW | 2.3 L/kW |
| Tensile strength | Medium | Medium | Low |
| Torque ripple | Medium | High | Medium (10%) Low |
| Maximum/base speed | Medium | High | Low |
| Demagnetization | No | No | Yes |
| Cost | Low | Low) | Low |

Due to its higher torque, reduced price, and reliability, the induction machine (IM) has long been used as an F-ESS [12]. In practice, the squirrel cage model is a less expensive and better option for the distribution and transmission grid systems that necessitate slow response application forms [13]. The permanent magnet machine (PMM), in contrast, hand, is increasingly being employed for F-ESS owing to its high power density, increased performance, and reduced rotor losses. This is frequently used in electrical grid systems for high-speed application areas [14]. Idling loss can be a massive disadvantage of the PMM system based on stator-eddy current losses and its tensile strength.

**Volume** 3, **Number** 1, May 2023
https://doi.org/10.47709/brilliance.v3i1.1941

### APPLICATIONS OF MESS WITHIN ELECTRICAL GRIDS

Mechanical energy storage systems (MESS) continue to play a critical role in ensuring a timely and well-coordinated response that meets the demands of utility power generators, transmission grids, distribution grids, and marketing assistance at all levels of the power grid. It is becoming abundantly evident that all these applications require a rapid response from MESS, as delays can be the root cause of the entire electrical grid's failure. To name a few power quality issues, voltage sag, voltage swell, voltage regulation, and frequency control all have a short time period (less than 60 seconds). Moreover, these can be high-power implementations or low-power implementations. MESS was successfully launched during the four major sub-schemes in power grids [15].

### CONCLUSIONS

This investigation makes available mechanical energy storage system (MESS) innovations, specifically CAES, PH-ESS, and F-ESS innovations, which make different MESS technologies appropriate for electricity grid application areas. Among some of the various MESS kinds, recent research is being conducted into energy storage system types such as F-ESS, which is used for short storage periods. Reduced mechanical, electrical, and power-conversion losses are essential considerations for flywheels ESS. CAES and PH-ESS are increasingly concerned with dependable innovations and cost-effectiveness. Regardless of its commercial significance, it is clear that CAES and PH-ESS can eliminate voltage disturbances while also achieving a maintainable emission reduction from the generation of electricity that harm the environment. Since many investigations have shown, the outcomes reveal a statistically significant gain in power grids based on MESS and renewable energy resources (RER). MESS innovations are intended to act as a catalyst in addressing the intermittent nature of renewable energy resources (RER), providing professional support as well as full financial advantages.

### REFERENCES

[1] M. M. Khaleel, M. R. Adzman, and S. M. Zali, "An integrated of hydrogen fuel cell to distribution network system: Challenging and opportunity for D-STATCOM," *Energies*, vol. 14, no. 21, p. 7073, 2021.

[2] M. M. Khaleel, T. Mohamed Ghandoori, A. Ali Ahmed, A. Alsharif, A. J. Ahmed Alnagrat, and A. Ali Abulifa, "Impact of mechanical storage system technologies: A powerful combination to empowered the electrical grids application," in *2022 IEEE 2nd International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering (MI-STA)*, 2022.

[3] M. M. Khaleel, M. R. Adzman, S. M. Zali, M. M. Graisa, and A. A. Ahmed, "A review of fuel cell to distribution network interface using D-FACTS: Technical challenges and interconnection trends," *Int. J. Electr. Electron. Eng. Telecommun.*, pp. 319–332, 2021.

[4] M. A. Aminudin, S. K. Kamarudin, B. H. Lim, E. H. Majilan, M. S. Masdar, and N. Shaari, "An overview: Current progress on hydrogen fuel cell vehicles," *Int. J. Hydrogen Energy*, 2022.

[5] A. Alsharif, C. W. Tan, R. Ayop, A. A. A. Ahmed, A. Alanssari, and M. M. Khaleel, Eds., *Energy Management Strategy for Vehicle-to-Grid Technology Integration with Energy Sources: Mini review*, vol. 1, no. 1. African Journal of Advanced Pure and Applied Sciences (AJAPAS), JANUARY-MARCH 2022.

[6] Y. Li, S. Miao, X. Luo, B. Yin, J. Han, and J. Wang, "Dynamic modelling and techno-economic analysis of adiabatic compressed air energy storage for emergency back-up power in supporting microgrid," *Appl. Energy*, vol. 261, no. 114448, p. 114448, 2020.

[7] A. Alsharif, C. W. Tan, R. Ayop, A. Ali Ahmed, M. M. Khaleel, and A. K. Abobaker, "Power management and sizing optimization for hybrid grid-dependent system considering photovoltaic wind battery electric vehicle," in *2022 IEEE 2nd International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering (MI-STA)*, 2022.

[8] M. Belrzaeg, A. A. Ahmed, A. Q. Almabrouk, M. M. Khaleel, A. A. Ahmed, and M. Almukhtar, "Vehicle dynamics and tire models: An overview," *World J. Adv. Res. Rev.*, vol. 12, no. 1, pp. 331–348, 2021.

[9] M. M. Khaleel, "Modeling and control a D-STATCOM with Sugeno fuzzy controller (SFC) and Mamdani fuzzy controller (MFC) for voltage sag mitigation," in *2nd International Conference on Emerging Trends in Engineering and Technology (ICETET'2014), May 30-31, 2014 London (United Kingdom)*, 2014.

[10] Z. Wang, W. Xiong, R. Carriveau, D. S.-K. Ting, and Z. Wang, "Energy, exergy, and sensitivity analyses of underwater compressed air energy storage in an island energy system," *Int. J. Energy Res.*, vol. 43, no. 6, pp.

**Volume** 3, **Number** 1, May 2023
https://doi.org/10.47709/brilliance.v3i1.1941

2241–2260, 2019.

[11] M. M. Khaleel, "Enhancement Power Quality with Sugeno-type Fuzzy Logic and Mamdani-type Fuzzy Logic Base on DVR," *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 3, no. 4, pp. 8273–8283, 2014.

[12] M. M. Khaleel, "Intelligent techniques for distribution static compensator using genetic algorithm, and fuzzy logic controller," *Int. J. Comput. Commun. Instrum. Eng.*, vol. 2, no. 1, pp. 15–20, 2015.

[13] M. M. Khaleel and K. Abduesslam, "DVR with artifcial intelligent controller for voltage sag mitigation," in *International Conference on Advances in Engineering and Technology (ICAET'2014) March 29-30, 2014 Singapore*, 2014.

[14] M. M. Khaleel, A. Alsharif, I. Imbayah, and K. Imbayah, "Renewable Energy Technologies : Recent Advances and Future Predictions," *African J. Adv. Pure Appl. Sci*, vol. 1, no. 3, pp. 58–64, 2022.

[15] A. A. Ahmed and O. S. M. Jomah, "Vehicle yaw rate control for Lane change maneuver using fuzzy PID controller and neural network controller," in *2020 IEEE 2nd International Conference on Electronics, Control, Optimization and Computer Science (ICECOCS)*, 2020.

[16] A. A. Ahmed, M. A. Masood, M. M. Khaleel, and A. Q. Almabrouk, "An investigation of the effect of the hub motor weight on vehicle suspension and passenger comfort," *Int. j. mech. prod. eng. res. dev.*, vol. 11, no. 5, pp. 51–64, 2021.