Conférence Internationale en Automatique & Traitement de Signal (ATS-2018)
Proceedings of Engineering and Technology – PET
Vol.35pp.69-79

Renewable Energy Storage Technologies - A Review

O. ACHKARI*1, A. EL FADAR*2

*Laboratoire de Technologies Innovantes, Université ABDELMALEK ESSAADI
BP 1818 Tanger Principal-Tanger-Maroc

[1]oussama.achkari@gmail.com
[2]aelfadar@yahoo.fr

Abstract - With the growing exploitation of renewable energy sources, the use of energy storage techniques becomes more and more unavoidable for overcoming the undesirable impacts of the renewable energy intermittency and ensuring the accessibility of electrical energy in remote regions.

The current study presents a review of the commonly used renewable energy storage technologies. A detailed comparison of various technical characteristics and features of these technologies is highlighted.

***Keywords*—Energy storage technologies; Renewable energy; Power quality.**

Introduction

From a general point of view, the foreseeable exhaustion of fossil fuels, the need to fight against global warming, the awareness for the protection of the environment and the consideration of sustainable development in energy policies have put renewable energies at the heart of a strategic challenge for the future of our planet.

The qualities of renewable energies are often overshadowed by one of their defaults: they produce intermittently and more or less predictably. In other words, it is difficult to rely on them systematically to integrate their production in a general and global pattern of power supply [1]. These sources of energy will never be programmable since we will never be able to command the sun to shine or the wind to blow. In order to ensure a balance between supply and demand at all times and everywhere, it seems essential to develop solutions to store these renewable energies [2].

Even if it has not yet reached maturity, energy storage has several advantages. First, some technologies constitute a real environmental gain, by allowing the large-scale deployment of renewable energies [3]. In addition, it provides electricity through centralized or decentralized energy systems [4], taking into account local and global constraints. Not to mention that is accessible to all the actors: industrialists, communities or individuals.

The current study presents a review of the commonly used renewable energy storage technologies. A detailed comparison of various technical characteristics and features of these technologies is highlighted.

I. Classification of Energy Storage Systems

Energy storage systems (ESS) can be used to balance electrical energy supply and demand. The process involves converting and storing electrical energy from an available source into another form of energy, which can be converted back into electrical energy when needed [5]. The forms of energy storage conversion can be chemical, mechanical, thermal, or magnetic. Based on diverse approaches currently being deployed around the world, researchers and scientists have classified storage energy technologies based on two main criteria as described in scheme below: i) the form of energy stored and ii) the time of discharge [6].

ISSN 2356-5608

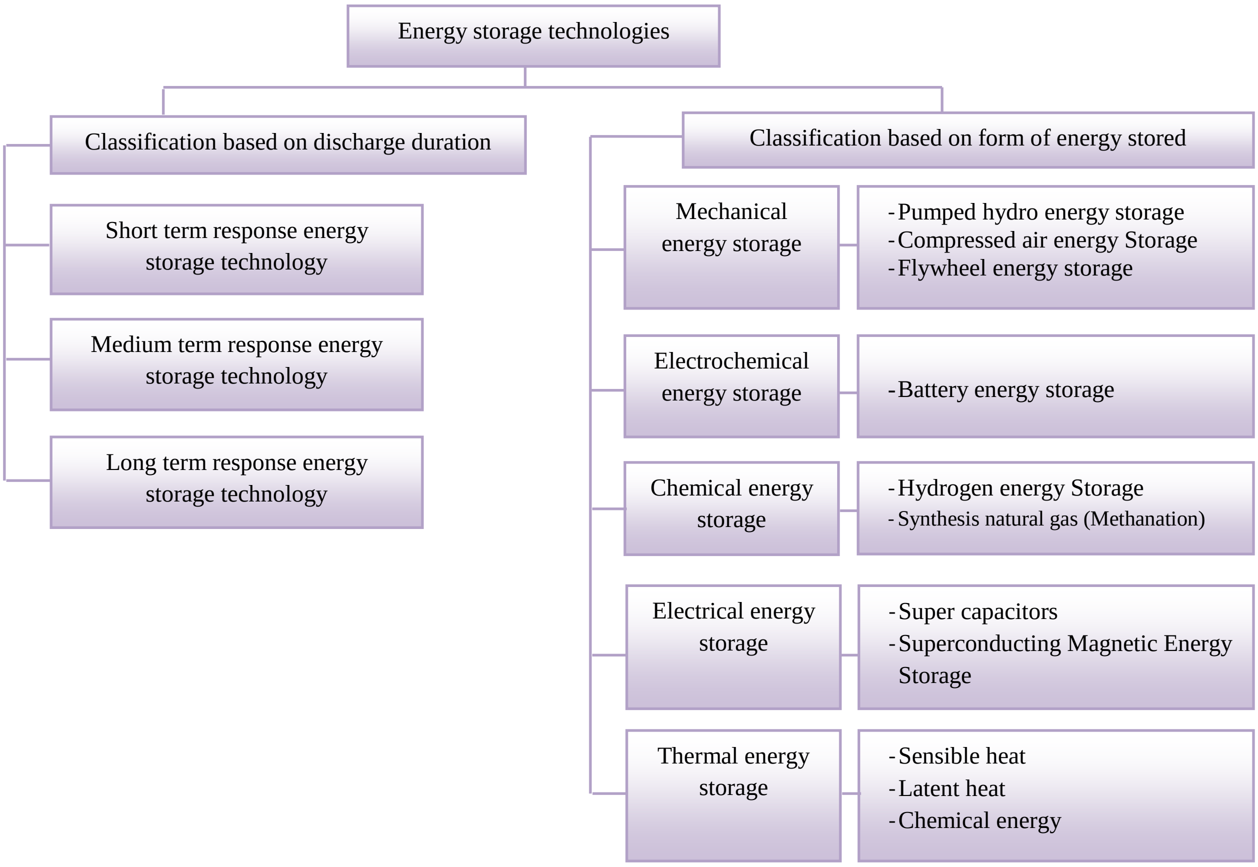


Fig. 1: Classification of energy storage technologies.

a. Classification based on discharge duration

Storage energy systems are divided on three categories depending on their power density and their response time [6]:

- Short term response energy storage system: this category of technologies has high power density and is capable to respond for short periods (few seconds or minutes).
- Medium term response energy storage system: this type is capable to hold and supply electrical energy from few minutes to hours.
- Long term response energy storage system: this kind is capable of withholding and supplying energy for real long-term (days, weeks, or months).

b. Classification based on form of energy stored:

1) Mechanical energy storage:

<u>Flywheel energy storage:</u>

The flywheel energy storage system (FESS) is a mechanical storage device which emulates the storage of electrical energy by converting it to kinetic energy which is stored in a rotating mass with very low frictional losses [7]. The input energy to the FESS is usually drawn from an electrical source coming from the grid or any other source of electrical energy. An integrated motor-generator speeds up as it stores energy and slows down when it is discharging.

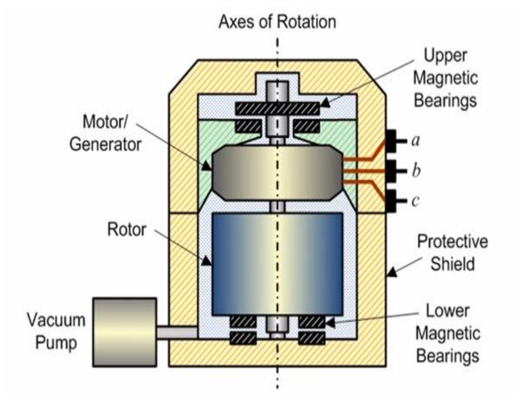
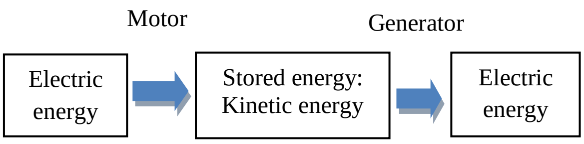


Fig. 2: Structure and component of a flywheel [8].

ISSN 2356-5608

Conférence Internationale en Automatique & Traitement de Signal (ATS-2018)
Proceedings of Engineering and Technology – PET
Vol.35pp.69-79

Concept scheme:



Advantages:

- High power density;
- Robust and well known technology of motors, inverters and rotating masses widely used in industry;
- No aging effects due to electro-chemical process and reactions;
- Long service life (more than 15 years);
- Wide operating temperature range compared to batteries;
- No capacity degradation, the lifetime of the flywheel is almost independent of the number and depth of charge/discharge cycles;
- Very high number of charge/discharge cycles possible;
- Short recharge time;
- Environmental friendly materials.

Disadvantages

- Many components to maintain (bearings, vacuum pump, cooling fans, control sensors), which all represent potential single points of failure;
- Relatively high complexity of durable and low loss bearings;
- Stress and fatigue limits for the mechanical parts;
- Relatively high parasitic operational and standby losses.

Applications:

Flywheel applications range from large scale at the electrical grid level to small scale at the customer level. The most common applications are power quality such as frequency and voltage regulation, pulsed power applications for the military, attitude control in space craft, UPS, load leveling and hybrid and electric vehicles [9].

Flywheels can also assist in the penetration of wind and solar energy in power systems by improving system stability and grid frequency balancing, due to their fast response characteristics.

<u>Pumped hydro energy storage (PHES):</u>

Pumped hydro plants, so far, is considered to be the only possible way to store energy in a huge amount while maintaining a high efficiency and being economical as well and has about 98 percent share of total global storage predominant in today's grid [10].

Basically, the system contains two water reservoirs at different elevations. In times of low electricity demand and high production, water is pumped from the lower reservoir into the higher, storing the electricity in the water in the form of potential energy. When needed, for example on peak demand, the water can be released, flowing down the pipes again and back through the turbine which then generates the electricity.

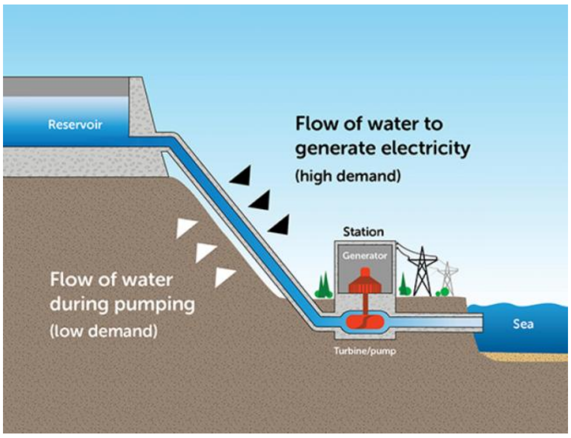
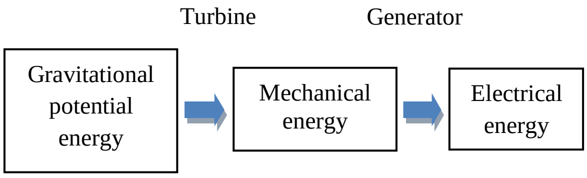


Fig. 3: Principal of a pumped hydro energy storage plant [11].

Concept scheme:



Advantages:

- PHES has a roundtrip efficiency of 70–80%;
- Anticipated lifetime of PHES is around 40–60 years;
- Mature technology, capable of storing huge amounts of energy;
- Fast response times;
- Inexpensive way to store energy.

Disadvantages

- Few potential sites;
- Huge environmental impacts;
- Huge water source requirement.

Applications

Pumped Hydro Storage is at present the only utilized method of large-scale grid energy storage. It can be used to provide substantial benefits to the energy system including frequency control, ramping/load leveling and peak shaving, load following, and provision of stand by reserve [12]. Due to the low energy density of pumped storage schemes they are really only applicable for large scale grid applications.

ISSN 2356-5608

Compressed air energy Storage (CAES):

The working principle of CAES is to use an electric compressor to compress air to a high pressure and store it in giant underground spaces. The pressurized air is discharged upon demand to create power again by extension of the air through an air turbine.

Depending on the procedure, CAES technologies are separated into, Adiabatic (A), Diabatic (D) and Isothermal (I) concepts [13]. Thus relying on the how heat is handled during the compression and the expansion of the air.

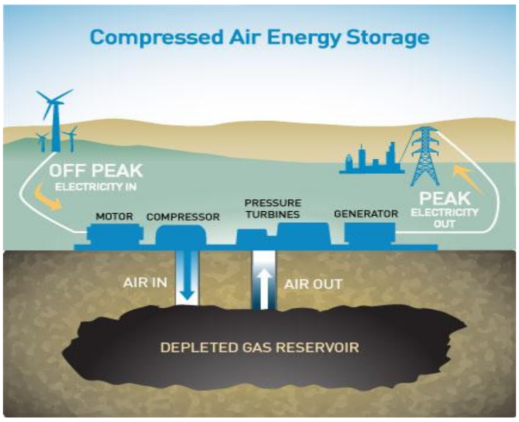
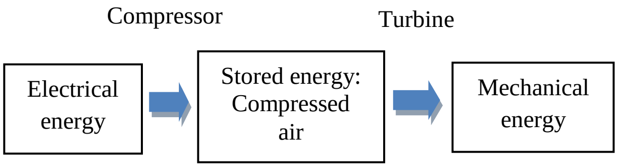


Fig. 4: Operating principle of compressed air energy storage [14].

Concept scheme:



Advantage

- CAES with assessed efficiency of 70% works well for about 40 years;
- Capable of storing huge amounts of energy, similar to PHE;
- Fast response times;
- Inexpensive way to store energy.

Disadvantages:

- Requires sealed storage caverns;
- Not yet fully developed;
- Economical only up to a day of storage.

Applications:

Although CAES is a mature, commercially available energy storage technology, there are only two CAES operated all over the world. One is in Huntorf in Germany; another is in Mclntosh, Alabama in USA [15]. Their ability to operate on a daily cycle makes them useful for load-following/peak shaving and energy management. It could also replace conventional battery system as a standby power which decreases the construction and operation time and cost.

2) Electrochemical energy storage (Batteries):

An EES system consists of a number of electrochemical cells connected between themselves, which produce electricity from an electrochemical reaction. Each cell contains two electrodes (one anode and one cathode) with an electrolyte which can be at solid, liquid or viscous states [6, 16]. During discharging, the electrochemical reactions occur at the anodes and the cathodes simultaneously. To the external circuit, electrons are provided from the anodes and are collected at the cathodes. During charging, the reverse reactions happen and the battery is recharged by applying an external voltage to the two electrodes.

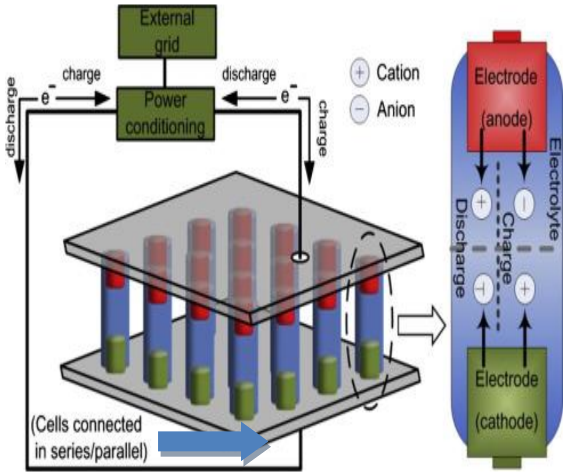
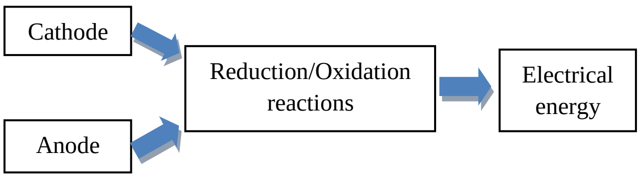


Fig. 5: Schematic diagram of a battery energy storage system operation [4].

Scheme concept:



Advantages:

- Easy and therefore cheap to produce;
- Mature technology, more than 150 years of experience and development;
- Easily recyclable;
- Highest energy density in commercial available batteries with huge potential;
- Lithium and graphite as resources are available in large amounts.

ISSN 2356-5608

Disadvantages:

- Very heavy and bulky;
- Rather short-lived;
- Environmental concerns: although pretty safe, some materials are very toxic and exposure can cause severe damage to people and animals;
- Corrosion caused by the chemical reactions;
- Complete discharge destroys the cells;
- Deteriorates even if unused;
- Some used materials are flammable in contact with atmospheric moisture.

Applications:

Battery storage technology currently provides the most widespread and satisfactory methods of storing relatively small amounts of energy for powering portable electrical devices. Several variants have also been used for grid applications, especially for power quality, UPS and short spinning reserve [17]. There are also several trials in systems for energy management.

3) Hydrogen energy Storage and Methanation

Water electrolysis technology is the most flexible and tenable solution to store renewable energy on a large, long-term scale. Using excess renewable electricity the Proton Exchange Membrane (PEM) splits water into its constituent parts, hydrogen and oxygen, that can be stored in common tanks. The resulting hydrogen may be consumed in one of three ways [4, 18]:

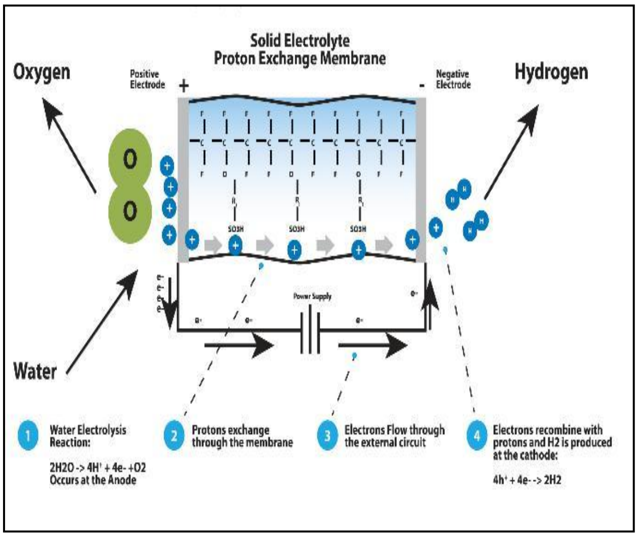


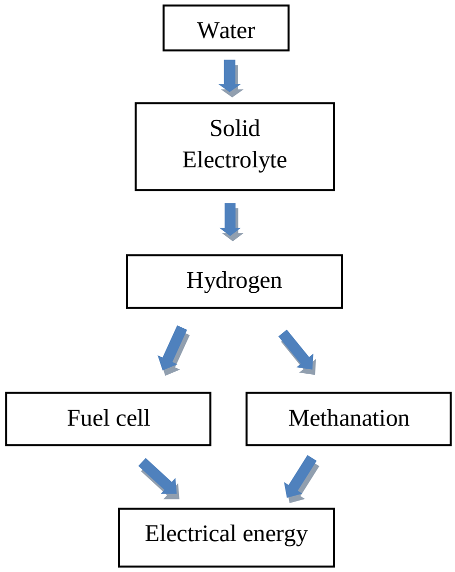
Fig. 6: Scheme of chemical process of hydrogen production [19].

Directly as a fuel: Hydrogen can be converted to electricity through a fuel cell or combustion engine (turbine or internal combustion engine).

As a feedstock: Hydrogen is an important feedstock for some advanced bio-fuel production processes. By biological or chemical combination of hydrogen and carbon dioxide we produce synthetic natural gas ($2H_2 + CO_2 \rightarrow CH_4 + O_2$), which can then be injected into natural gas pipelines.

Blended with natural gas: hydrogen may be injected into some natural gas pipeline systems to supply infrastructures or end-use devices.

Concept scheme:



Advantages:

- Clean sustainable way of storing energy;
- Capable of storing huge amounts of energy;
- Capable of storing energy for several days, even months.

Disadvantages:

- Very low efficiency (30 – 40 percent);
- Energy loss amid a single cycle (from hydrogen production to electricity generation from fuel cell);
- Requires very sophisticated grid.

Application:

The versatility of stored hydrogen gas placed it at the center of new renewable energy infrastructure development; it could be turned back into electricity for the grid, it could be transformed to ammonia and used to fill fuel cell electric vehicles. Or be combined with carbon dioxide to produce synthetic natural gas [19]. This can be piped straight into existing natural gas infrastructure. It is also well suited to peak shaving and energy management applications in which hydrogen is generated at off-peak times or when output from renewable sources is large.

ISSN 2356-5608

4) *Electrical energy storage:*

Superconducting Magnetic Energy Storage (SMES):

The system consists of three major components: the coil, the power conditioning system (PCS) and a cooling system. The idea is based on the fact that a current will continue to flow in a superconductor even after the voltage across it has been removed. When the superconductor coil is cooled below its superconducting critical temperature it has negligible resistance, hence current will continue to flow (even after a voltage source is disconnected) [6, 20]. The energy is stored in the form of a magnetic field generated by the current in the superconducting coil. It can be released by discharging the coil.

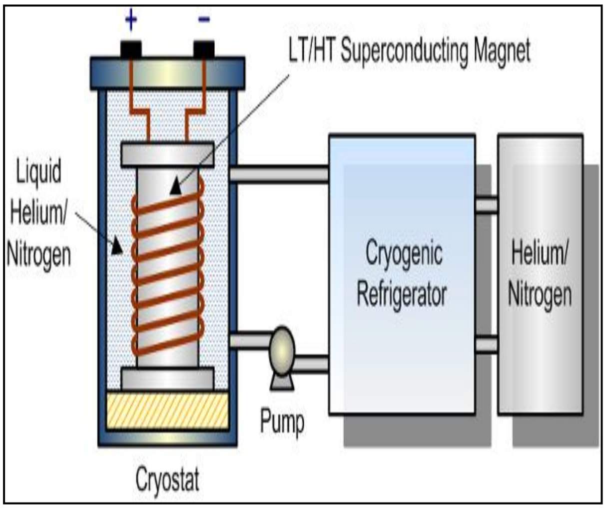
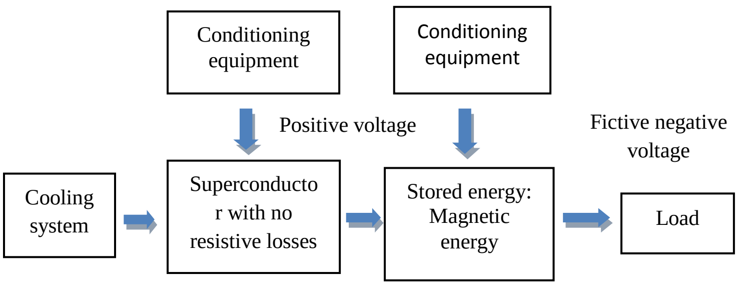


Fig. 7: Scheme of the main component of SMES system [21].

Concept scheme:



Advantages:

- Fast response times;
- Capable of partial and deep discharges;
- No environmental hazard.
- Absence of moving parts and high cycling efficiency;

Disadvantages

- Very expensive in production and maintenance;
- Reduced efficiency due to the required cooling process (needs of large amount of power).

Applications:

Superconducting magnetic energy storage systems can be used to reduce low frequency oscillations to enhance transmission capacity and boost voltage stability. They can also be used in power quality applications to offer energy to flexible AC transmission [20].

On the other hand, SMES is suitable to mitigate the negative impacts of renewable energy in power quality related issues, especially with power converters – needed for solar photovoltaic and some wind farms – and wind power oscillations and flicker.

Super capacitors:

Super capacitors are governed by the same fundamental equations as conventional capacitors, but utilize higher surface area electrodes and thinner dielectrics to achieve greater capacitances [22, 23]. In doing so, super capacitors are able to attain greater energy densities while still maintaining the characteristic high power density of conventional capacitors.

When a voltage is applied to a capacitor, opposite charges accumulate on the surfaces of each electrode. The charges are kept separate by the dielectric, thus producing an electric field that allows the capacitor to store energy.

ISSN 2356-5608

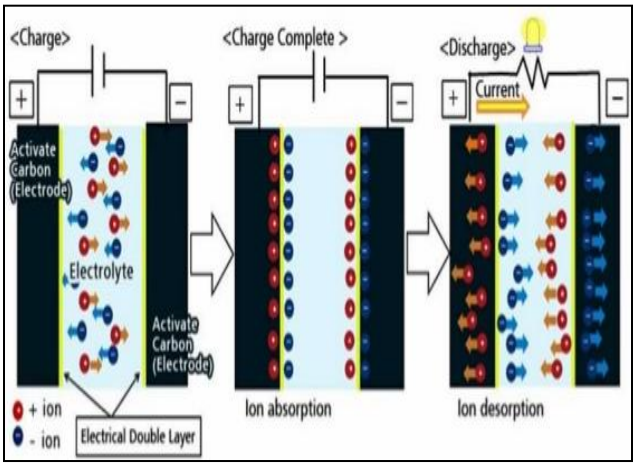


Fig. 8: Scheme of operational process of a super capacitor [24].

Advantages:

- Long cycle life;
- High current capability;
- Very high efficiency;
- Wide temperature range;
- Wide voltage range.

Disadvantages:

- Low voltage cells; to get higher voltages, serial connections are required;
- Voltage balancing needed; when more than 3 super capacitors are connected in series, the circuit needs a voltage balancing element;
- High self-discharge as compared to electrochemical batteries.

Application:

Most current applications rely on combining super capacitor and battery technology, in order to combine the power performance of the former with the energy storage capability of the latter. Super capacitors have potential applications for PV integration as they can be used to alleviate voltage swings from large PV-installations that otherwise pose operational issue on the grid [25].

5) *Thermal storage*

Thermal energy storage (TES) includes a number of different technologies. Thermal energy can be stored as sensible heat, latent heat and chemical energy (thermo-chemical energy storage) using chemical reactions [26].

Thermal energy storage in the form of sensible heat is based on the specific heat of a storage medium, which is usually kept in storage tanks with high thermal insulation. The most commonly storage medium is water but rock, sand, clay and earth can also all be used. Sensible heat storage is relatively inexpensive, but its drawbacks are its low energy density and its variable discharging temperature [27]. These issues can be overcome by phase change materials (PCM) which can offer a higher storage capacity that is associated with the latent heat of the phase change [28]. The change of phase could be either a solid/liquid or a solid/solid process. Finally, High energy density TES systems can be achieved using chemical reactions. Thermo-chemical reactions, such as adsorption (adhesion of a substance to the surface of another solid or liquid), can be used to store heat and cold, as well as to control humidity.

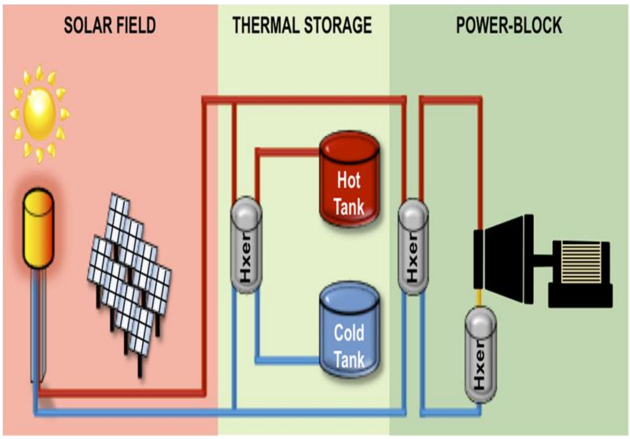


Fig. 9: scheme of sensible heat storage installation [29].

Concept scheme:

Solar rays → Stored energy: Heat → Electrical energy

Advantages:

- Enormous turn-down capability as thermal energy storage excels at meeting small cooling loads, whereas chillers are ill-equipped to operate at very low capacities.
- Preserving limited electric power capacity for other important functions or expanding electric loads.
- Emergency cooling for mission critical loads.
- Avoids chiller vibration and noise for noise-sensitive applications such as performance venues.
- Balanced electrical and thermal output for cogeneration systems.
- Can be discharged over short or long durations, extending over the entire cooling period or selected intervals.
- Remarkably high round-trip efficiency.
- Capability to recover up to 99% of the stored cooling.

ISSN 2356-5608

Disadvantages:

- Material properties and stability, each storage application needs a specific design to fit specific boundary conditions and requirements.
- More complex systems (i.e. PCM, TCS) require R&D efforts to improve reacting
- materials, as well as a better understanding of system integration and process parameters
- TES market development and penetration varies considerably, depending on the application fields and regions.
- Additional cost and complexity

Applications:

Important fields of application for TES systems are in the building sector (domestic hot water, space heating, air-conditioning) and in the industrial sector (process heat and cold). TES systems can be installed as either centralized plants or distributed devices to store waste or by-product heat or renewable heat when it is available and supplying it upon demand. TES systems can also help integrate renewable electricity from PV and wind [26].

II. Comparison

Unlike the other domains, the efficiency and the investment cost are not the only indicators to choose the suitable energy storage technology for the adequate application. Indeed, the main characteristics of storage systems on which the selection criteria are based are the following:

Storage capacity, available power, depth of discharge power, discharge time, autonomy, cost and environmental impacts, etc.

The table below gives a heads up of some selecting key criteria for different applications:

Table 1: Some selecting key criteria of energy storage technologies for different applications.

Applications	Key criteria	Storage system	Explanation
low-power permanent applications	self-discharge	lithium-ion battery	The lithium-ion battery is the best candidate for its lowest possible self discharge.
small and large systems in isolated areas	Autonomy and cost	lead battery	The lead battery remains the best compromise between performance and cost. Lithium-ion has better performance but is still far too expensive.
peak-hour load leveling	high-energy storage	compressed air and flow batteries	Although, they have a cost advantage, but these technologies have not yet been tested in the field.
power quality	energy release capacity and cycling capacity	flywheels and super-capacitors	The other choices have limited durability and are unreliable.

Among the choices, chemical batteries always satisfy the technical criteria of all the applications, but have limited durability and most of the times are too expensive. Nowadays, the only commercial available technologies to store large amounts of energy providing for several hours to days and are able to fulfill the needs of storage for intermittent energy supplies for large scale are: hydraulic and thermal storage.

The comparative study of different storage solutions cannot be done without taken into account the economic aspects. Thus, for each technology, capital costs which can be reduced, in terms of power or energy, as well as operating costs, are to be taken into consideration. In addition, the costs of replacement (and replacement frequencies) of technologies should be considered.

An estimation of the technical and economic data for the main storage technologies are summarized in the table below.

ISSN 2356-5608

Table 2: Comparison of the different energy storage technologies [30]

Technology	Capacity	Power	Response time	Investement cost (€/kW)	Life time (Charge/Discharge cycle)
PHES	1 to 10 GWh	0,1 to 2 GW	10 min	600 to 1 500	11 000
CAES	10 MWh to 10 GWh	15 to 200 MW	1 min	400 to 1 200	11 000
Hydrogen	10 kWh to 10 GWh	1 kW to 1 GW	100 ms	3000 to 5 000	25 ans
Batteries	1 kWh to 10 MWh	0,01 to 10 MW	1 ms	300 to 3 000	500 to 4 000
flywheel	0,5 to 10 kWh	2 to 40 MW	5 ms	3 000 to 10 000	> 10 000
Super capacitors	3 kWh	Tension : 2,5 V	3 s	-	> 10 000
Superconducting Magnetic Energy Storage	0,3 to 30 kWh	-	8 ms	-	> 10 000

Beyond technical and economic interests, energy storage is part of a global strategy to achieve a carbon-free energy mix. The large-scale deployment of intermittent energies cannot be achieved without the development of countervailing solutions. The current use of CO2-emitting technologies to mitigate the intermittence of renewable energy production is not a long term solution. The coupling of intermittent renewable energies and storage makes sense in the search for environmental coherence of energy policies.

III. Opportunities:

As explained in previous sections, energy storage remains by far the key to integrate renewable energies into energy policies in the future. That is why many research organizations and the major energy companies have therefore reconsidered the question of storage energy and they invested in multidisciplinary projects related to energy storage. Among the most promising sectors, we find:

Establishment of the "hydrogen" sector: Researchers are as interested in the production of hydrogen by electrolysis as its storage through hydrides, in tanks or in fuel cells.

Improve the maturity of the other different possible ways of storing energy: This research concerns the study of batteries, super capacitors, superconductivity but also the analysis of materials and life cycles.

Search for micro-energy sources for some specific applications: Many sources of micro-energy are currently developed: micro-batteries and micro-fuel cells and sources of energy recovery (temperature differences, vibrations, etc.).

Research on the components required for electric and hybrid vehicles: Research in this area is focused on fuel cells and batteries, but also on motor drives and habitat / transport convergence.

IV. Conclusion

To meet the future needs of delocalized production and answer to the environmental standards, energy storage should be technologically improved. Chemical batteries are very performant, but are too much expensive for applications in remote areas. The recycling and waste management of these batteries still need R&D work. For network applications, the most appropriate technologies (flow batteries, compressed air, super-capacitors and flywheels) are more or less mature technologies and could be made more cost effective, more reliable and more efficient. For large scale applications, hydraulic and thermal storage remain the best candidates. The idea of storing the energy in hydrogen or methane is not desirable due to the low efficiency but is still likely to play a role in the future because of the great storage potential.

ISSN 2356-5608

References

[1] Kazuya Kubo, Yoshinori Kawaharazaki, Hideaki Itoh. Development of large MH tank system for renewable energy storage. International journal of hydrogen energy 2017; 4 2: 22475 – 22479.

[2] Pascal Dubucq, Prof.Dr.-Ing.Guunter Ackermann. Optimal Use of Energy Storage Potentials in a Renewable Energy System with District Heating. Energy Procedia 2017; 135:158 -171.

[3] D.O. Akinyele, R.K. Rayudu. Review of energy storage technologies for sustainable power networks. Sustainable Energy Technologies and Assessments 2014 ; 8 :74–91.

[4] Xing Luo, Jihong Wang, Mark Dooner, Jonathan Clarke. Overview of current development in electrical energy storage technologies and the application potential in power system operation. Applied Energy 2015; 137: 511–536.

[5] Miguel Miguel, Teresa Nogueira, Florindaa Martins. Energy storage for renewable energy integration: the case of Madeira Island, Portugal. Energy Procedia 2017; 136: 251-257.

[6] Amit Kumar Rohit, Ksh. Priyalakshmi Devi, Saroj Rangnekar. An overview of energy storage and its importance in Indian renewable energy sector. Journal of Energy Storage 2017;13:10–23.

[7] Mustafa E. Amiryar and Keith R. Pullen. A Review of Flywheel Energy Storage System Technologies and Their Applications. Applied Sciences 2017.

[8] Electrical Funda Blog. Flywheel as Energy Storage Device, Calculations and Rotor Requirements. http://electricalfundablog.com/flywheel-energy-storage-calculations-rotor.

[9] Electric Power Research Institute. Electricity Energy Storage Technology Options. A White Paper Primer on Applications, Costs, and Benefits 2010.

[10] Electricity Advisory Committee. Energy Storage Activities In the United States Electricity Grid 2011.

[11] EnergyAustralia. Outlines plans for 100MW pumped hydro plant in SA. http://reneweconomy.com.au/energyaustralia-outlines-plans-for-100mw-pumped-hydro-plant-in-sa-68973.

[12] Thang Ngoc Cong , WeiYang, Chunqing Tan, Yongliang Li, YulongDing. Progress in electrical energy storage system: A critical review. Progress in Natural Science 2009; 19: 291-312.

[13] Young-Min K, Jang-Hee L, Seok-Joon K, Daniel F. Potential and evolution of compressed air energy storage: energy and exergy analyses. Entropy 2012; 14:1501–21.

[14] Sandia National Laboratories. Advanced Underground Compressed Air Energy Storage. https://www.energystorageexchange.org/projects/139.

[15] Global Energy Network Institute. Energy Storage Technologies & Their Role in Renewable Integration. July 2012.

[16] Gabash A, Li P. Active-reactive optimal power flow in distribution networks with embedded generation and battery storage. IEEE Trans Power Syst 2012;27(4):2016–35.

[17] K.C.Divya, Jacob Ostergaard. Battery energy storage technology for power systems - An overview. Electric Power Systems Research 2009; 79: 511-520.

[18] Díaz-González F, Sumper A, Gomis-Bellmunt O, Villafáfila-Robles R. A review of energy storage technologies for wind power applications. Renewable Sustanable Energy 2012;16:2154–71.

[19] Renewable Energy World. Hydrogen Energy Storage: A New Solution To the Renewable Energy Intermittency Problem. http://www.renewableenergyworld.com/articles/2014/07/hydrogen-energy-storage-a-new-solution-to-the-renewable-energy-intermittency-problem.html.

[20] Buckles, W. & Hassenzahl, W., 2000. Superconducting Magnetic Energy Storage. IEEE Power Engineering review 2000; 16: 16–20.

[21] Energy Storage Sense. Superconducting Magnetic Energy Storage. http://energystoragesense.com/superconducting-magnetic-energy-storage-smes/

[22] Marin S. Halper, James C. Ellenbogen. Supercapacitors: A Brief Overview. MITRE Nanosystems Group 2006.

[23] Teleke S. Energy storage overview: applications, technologies and economical evaluation. White Paper, Quanta Technology, 2011. p. 1–11.

[24] Power Electronic Tips. The fundamentals of supercapacitor balancing. https://www.powerelectronictips.com/fundamentals-supercapacitor-balancing.

[25] Rahul Nema, Anurag Trivedi. Application of Super Capacitor Based Energy Storage System for Power Quality Improvement of a Decentralized Power Plant. International Electrical Engineering Journal 2013 ; 4 : 846-855.

[26] IEA-ETSAP and IRENA. Thermal Energy Storage Technology Brief E17, January 2013.

[27] Satyawan Singh, Pradeep Kumar Sharma, Neeru Goyal, Prashant KumarTayal. Thermal Energy Storage: A Process To Increase Efficiency and To Save our Environment. ICLISEM 2016; 81-87.

[28] El Fadar Abdellah. Novel Process for Performance Enhancement of a Solar Continuous Adsorption Cooling System. Energy 2016; 114: 10-23.

ISSN 2356-5608

[29]Joseph Stekli, Levi Irwin and Ranga Pitchumani. Technical Challenges and Opportunities for Concentrating Solar Power With Thermal Energy Storage. Journal of Thermal Science and Engineering Applications 2013 ; 5(2)

[30] Commission de régulation de l'énergie. Smart grids-CRE.
http://www.smartgridscre.fr/index.php?p=stockage-comparaison.