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A Review on Energy Storage System of Smart Grid System

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Abstract: ***As growing population in this world, the power consumption is increasing with respect the population, at this time more solar and wind power generation work together generate the power own field. at this time too much shorter of the energy consumption that is require to store some energy. Due to some mismatch of peal hour demand consumption of power it is necessary to store the energy. The smart grid defined as the something of the ecosystem with communicate with the virtual self- ware system also it will require some advanced tool for planning and operations. In some year back mostly smart grid used in renewable energy due to economical and environment friendly. Energy storage system with collaboration of smart grid give a bright impact on our future. With the help of various communication and control feature it is possible to established the energy storage system as well as battery storage system. This paper gives all the detailed to store the energy in smart grid manner.***

Keywords: Battery, smart grid, power quality, energy storage system

1. Introduction

As increasing the population system, the world electricity system has a no. of issue in certain era as like infrastructure, demand of supply, integration of renewable energy source with the DGs electric and hybrid vehicle and improve the securing of power supply and need less the carbon di-oxide. These issues are point out the economical disturbance and some environmental issue. But the smart grid not just meet these challenges but also give the sustainable energy system that is more efficient and more reliable. If we see that energy storage system is not latest idea but it is the fundamental idea for generation and transmission and distribution system also. But increasing the demand of energy most of the electricity grid apply the fossil fuel to store the energy. If we saw that without the fossil fuel only wind and solar power generation possible and these are given the output with fluctuations. And this generation of power is given the sustainable environment of this generation. Main advantage of this plant it located anywhere according to its requirement. Compared to the other industries the electricity grid has largest industry in India which generates the power 24*7. The smart grid will provide the power quality and less economy, give the storage option, and enable the active participation by consumers. In renewable generation system has a most important role of storage the electricity. Energy storage can give the flexible and more reliable power and in other way it is backup to intermittent of renewable energy.

In this paper we give the review all the energy storage system. This paper is divided in to three-part 1 part we know about the mart grid and its principal characteristic, 2part we discuss the energy storage and need of this and 3 part we discuss all type of energy storage system and then conclude this review.

2. Smart Grid: Technology and Principle

In our language the smart grid system is digital automation system of electricity which is do the monitoring and control and analysis with the supply chain, also it reduces the workforce and it will target sustainable and reliable safe and quality electricity to all consumers. In technical term smart grid can be defined as a smart electrical network which is combined the all type of electrical network and digital communication technology. The main advantage of this system is that it is capable of providing the power in each and every situation from multiple distribution sources like wind turbine and solar power system and integration of both this system also some time even plugin hybrid vehicle. It also helps the economical and stakeholder to operate all the parts of the system as efficiently as possible. Smart grid is bringing the power network with integrated with the electrical system with various type of technologies also it controls the energy use and also improve the power grid operation. This is accommodating with the large centralized power plant. Main thing is that the design should be correct and operate at market efficient for consumers. In smart grid most of the part is must be exploited managed are energy, capacity and location and time and the quality. These technologies generally grouped into following key technology area as like 1. Intelligent appliance 2. Smart power meter 3. Substations 4. Conducting cable 5. Integrated communication.

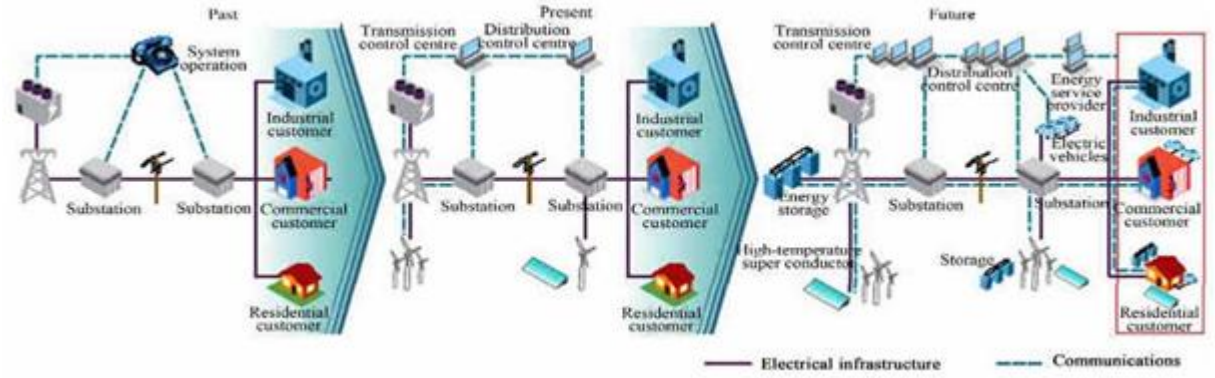

Figure 1: Smart grid with electricity system

- **Intelligent appliances**: - It has capable of deciding when the energy consume energy based on customer demand .it is also help full to reduce the peak load demand which is literally helpful to reduce the power generation costs like sensor, temperature sensor.
- **Smart power meter**: - This provides the two-way communication between the provider and the consumer in written and printed manner to give the automated billing data to consuming the electricity, detect the failure device and replace that.
- **Smart substations**: - Substation include the all type of monitoring and controlling the non-critical and critical data like breaker and power factor and breaker and transformer. Actually, substation is the main part of the smart grid from various station power comes to the end of substation and this substation provide the electricity to the consumer end. Also, substation require to split the electricity from one end to another end like transformer, switches, circuit breaker, capacitor and relays.
- **Super conductive cable**: - These cables are providing and long-distance transmission of power and automated monitoring and detect the faulty section and some failure due to weather and outage.
- **Integrated communication**: - Integrated communication in smart grid is done by PLC (programmable logic controller), SCADA and wireless cellular.

Advanced metering infrastructure

AMI is the term of which is describe the whole infrastructure from smart meter to two-way communication network to control the equipment and all the component gathering the all information and transfer the energy in real time. In other way AMI makes two-way communication easily with the customer and yes, it is backbone of smart grid. The main objective of AMI is to read the error of the data, network problem. Load profiling and energy audit etc. AMI consist of hardware and software component and all this play a measuring the energy consumption and transfer the information about the energy.

Energy storage system

Electrical energy storage system is very key role in smart grid. The main role of this is depends upon the charging and discharging cycle and the duration of their operation. As I above mentioned that it reduced the cost and improving the efficiency. Energy storage system useful for the consumer such as industrial user for peak shaving and minimize the electricity bill and that varies according to their highest power demand. In modern power distribution system where most of the highest electricity demand is completed by the renewable energy and the energy storage system is filled out the power consumption in high peak demand for store the electrical energy. Basically, the grid energy storage system is collection of the different type of energy storage which is used when the power fall down and need for the power. The energy storage may be large scale storage and some time it is short scale storage basically, it depends on the storage system. Energy storage is capture of the energy which is produced by the different source like wind, solar, hydro etc. and this energy produced at one time for use for the purpose of reduce the imbalance energy system between the energy demand and energy production because some time the energy demand goes high and some time energy demand goes low that time the energy storage managed this problem. The development of battery storage is managed this problem to store the energy in peak hour and this peak hour is indicate to the production peak time and then this storage release that in peak demand hour. The main work of this energy storage system to store the capacities that can be obtained by the various source like wind, solar, hydro etc. mostly energy storage divided to the 4 categories 1. Device large power (750MWH) 2. Storage device (>100MWH) 3. Medium power storage (1-50MWH) 4. Storage capacities (5-100MWH). Energy storage system improve the efficiency and reliability of the electric supply in peak load hour. And as I mentioned storage also provide the frequency regulation for maintaining the balance between the energy in peak load hour. We know that some power electronics equipment is used to long transmission line for controlling, thus the energy storage and power electronics hold sustainable promise for the transforming the electric power supply.

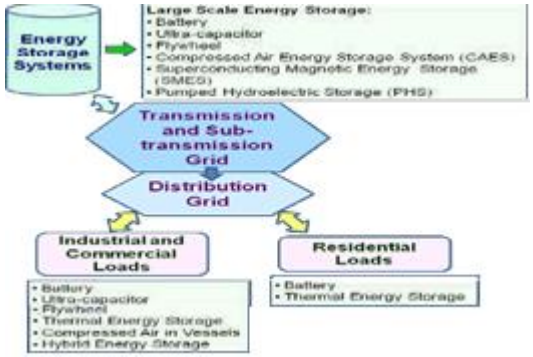

Figure 2: Energy storage devices

Available energy storage system

Energy storge system means that the storage of generated energy which is generated in previous time for a use of later time. Electric energy storge system vary in the various form in India which can be stored. They include for storage system batteries (10200MW), pumped storage hydro power (250- 1000MW), flywheels (10-20MW) and gas pressurized storage system (0-180MW). For reduce the gap between the demand and supply of electricity the energy storage system doing help.

Batteries

The working process of the battery is that it has a one or more electrochemical cell which converts the chemical energy in to the electric energy. If we see that batteries are old storage device and much help full to reduce the power consumption in off peak load hour. The battery storage system is modular and unique. Batteries storage capacities are mostly in 100 watts to several mega watt in their own requirement to fulfill that place. Batteries is placed in different areas as like generation and distribution, transmissions, customer vice, for inverter charging and provide the supply, batteries playing a very good role in their field. Most of the electric vehicle is used the batteries for starting and running on road of the vehicle.

The grid scale BESS consist the battery bank, control system and power electronic equipment for interfacing with the circuit. And situated transformer convert the required voltage of a battery for sending end voltage. In a battery bank number of batteries is connected together in face of series and parallel and both are together and individually according to the requirement. In last era the use of lead acid battery is much slower that's why more new batteries with new technologies are coming in to the market, which has long life, less cost and last longer than the lead acid batteries. Some new batteries with new technologies are lithium ion, lithium polymer, nickel metal hydride (NI-MH), sodium sulfur (NaS).

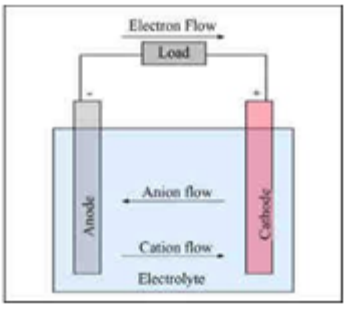

Figure 3: Working principle of battery

Table 1: Comparison of different type of batteries

Type	Energy density	Energy efficiency	Power density	Cycle life	Self-discharge
Lead acid	40	90	179.9	200-2000	4
li-ion	250	90	1799.9	2000	10
li-polymer	200	70	3000	>1200	8
Ni-MH	80	70	1000	500-100	30
NaS	150	90	150	>16000	<1

Ultra-capacitor

Ultra-capacitor is also known as the super capacitor and electric double layer which main work to store the electric energy in their bank without any chemical reaction as like batteries. The main part of this is electrolyte and electrodes which taking a part to store the energy in the form of electrical energy E which is stored in the form of charge Q with the voltage of V and the rising formula is

$$E = \frac{1}{2}cv^2 = \frac{1}{2}Qv \quad \ldots\ldots\ldots\ldots\ldots 1$$

In the ultra-capacitor the capacitance C is proportional to the area A of the plates and permittivity of the dielectric and inversely proportional to the distance between the plates. It has a long life due to n chemical processing in inner process. They have stored the energy in physical mode. When the charge stored in the electrode by the help of physical it provides the power density. The temperature goes for operating between -40 degree C to +65-degree C. it has a variety to control the energy storage system in large scale in multiple KV sector. They also short out the other issue like power quality, frequency control and voltage regulation. In some past year they have some new technology like they implemented with the nano tube in inner part for store the energy to improve the surface area of the capacitor. And this nano tube is improving the ultra-capacitor power density also and we know that its charging and discharging speed very fast. Some type of disadvantage of that like it has limited energy storage and very less density approximate 20%.but in coming year it will be resolve and density will grow up. Its number of cycle and temperature range is excellent. It can be suitable for the fast speed and transient stability and also it allows the high current charging. Yes, it is still in development condition but upcoming year it will be more sufficient the battery.

Figure 4: Ultra-capacitors with 3000 farads

Flywheel

Few many last year most of the industries are used the flywheel technology to stored the energy and this technology is very sufficient with other and the main advantage of this technology due to its high dynamic and long life, it has been the enhancement with the electric power quality and grid voltage and frequency support. It consists the flywheel coupled a permanent magnet synchronous machine. When the motor run the energy is stored in the form of momentum in a rotating wheel or cylinder. Mostly the flywheel uses the electricity to run the motor and high speed and reduce the speed also when the motor run at high speed the electrical power transformed in to a mechanical power and stored, flywheel drive the generator and generate the power. Some time for manufacturing the flywheel is use the composite material for losing the weight and motor runs at high speed. In the flywheel the motor used as a generator when the release energy by reversing the process the flywheel released it stored energy and it shows that it fully discharged. Mostly the stored energy is depending upon the rotational velocity and the inertia where the motor move. Main advantage of this technology is used superconducting magnetic bearing with the permanent magnet bearing which is increasing its life and energy density also.

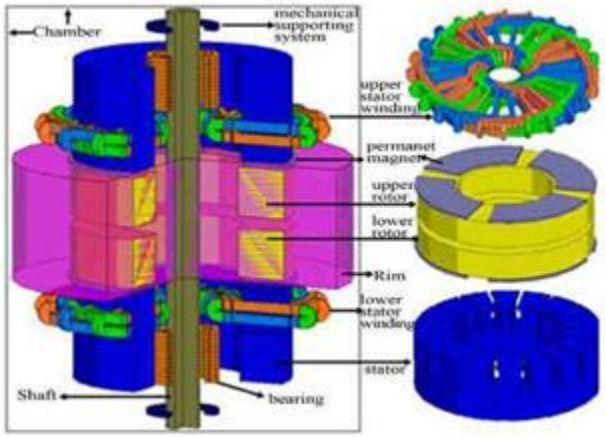

Figure 5: Flywheel

Superconducting magnetic energy storage (SMES):

It stored the energy when the direct current flow in the super conducting coil which is created by the magnetic field and also it cooled down the temperature. It consisting the three parts superconducting coil, power conditioning system and cooled refrigerator. When the coil is fully charged then the current will not flow into the system and the energy will stored automatically. Mostly the inverter and rectifier are used to change the AC power to DC power and DC power to AC power. When the stored energy released then the coil is discharged and the same process will repeat. Yes 2-3% energy loss when the current property will change. It has been used in short duration due to it high energy requirement for cooling and it also improve the power quality system. It is highly efficient and has a round trip efficiency is greater than 95%. Actually, its working principle is based on inductive energy storage in the magnetic field which is produced by the current. It consists of the 4 major subsystem 1. Super conducting with coil 2. Power condition which is control the flow of current 3. Cryogenic system which is maintain the temperature 4. Control unit.

In SMES the stored energy E and rated power P specified in each and every SMES devices

$$E = \frac{1}{2} li^2 ; P = \frac{dE}{dt} = LI \frac{dI}{dt} = VI \ldots\ldots\ldots 2$$

in this given equation the L is the inductance of the coil and I is the DC current.

Mostly the SMES is used with the FACTS device to stored the energy and improve the power quality and that's why it attaches with the STATCOM due to it has primary frequency control and has a high efficiency approximate 95 to 98. Several SMES in the range of KW to MW with the scale of already implemented for compensated of load as well as storage.

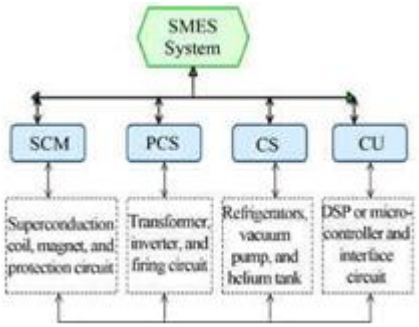

Figure 6: Block diagram of SMES Compressed Air energy storage system

CAESS is used at the storage of energy in the form of air and yes, it is used in one time as energy and other time it used as a compressed air. Basically, it is a long-term hybrid technology for generation. It consists the power train motor that drives a compressor, high pressure turbine, low pressure turbine and generator. Approximately 66 % of gas are used at the time of generation, in the time of generation the compressed air is driven in the off-peak hour in electrical power which is coming from the motor end and stored in the large storage reservoir. When the GT is producing the electricity during peak hour then the air is released and used in GT cycle. On the demand side the air is reverse and returns to the surface and this air is used to burn the natural gases in the combustion chamber. In CAESS the amount o gas is very less due to this reason the GT work simultaneously and CAESS produced the three time more electricity. As like reservoir made by the man type but this is so expensive due to this reason the location of this is very far from the society. When the fresh water is pumped into the cavern and present salt must be dissolves and then it will saturate the fresh water. Most of the case the CAESS is used to store the energy is electricity and gas both so due to this its efficiency is difficult to predict. But for approximation it finds out the its efficiency is 64%. In last few years the researcher is found to improve that efficiency of turbine and heat transfer chamber. As like air hear energy is stored separately but recovered by the air turbine.

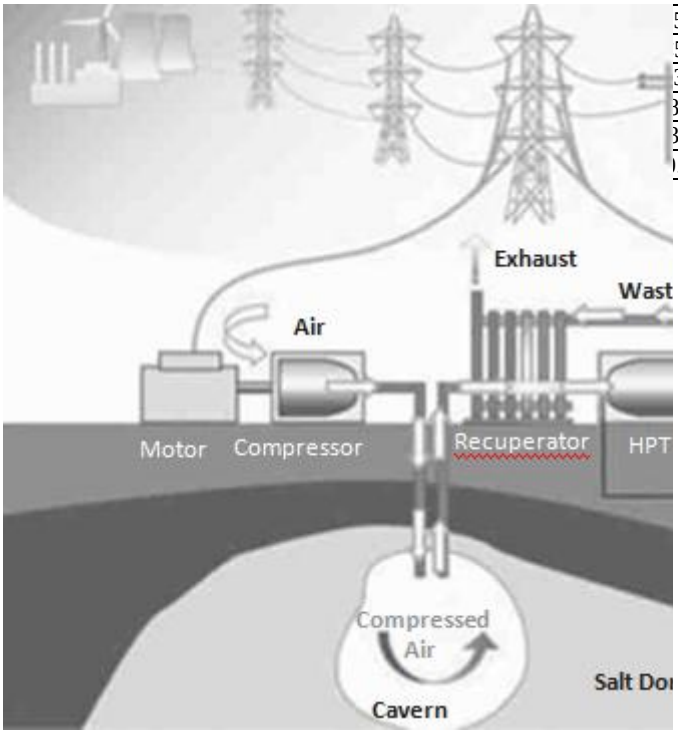

Figure 7: Caess

Pumped hydroelectric storage

PHES has a most nature and large capacity storage available. For this storage purpose a turbine and pump joined together. It consists two large reservoir at different locations and number of pump turbine. When the demand of power is not needed the water is coming from low reservoir to high reservoir where it stored. When the power is needed then upper side reservoir is open and the water is down the blade of turbine and the generator id produced the electricity. And this process is much similar to the conventional hydro electrical storage. The efficiency of this storage is approximately 50 to 85 %. since 1904 it is in working area due to its flexibility. It consist the two large reservoirs one is base level and second is other location. The waste water is sent back to the reservoir by the help of hydraulic turbine and approximate 1000MW it can be generating. And this pumped water has a large generation of electricity in a huge capacity. It has a fast start, and fast unloading capabilities.

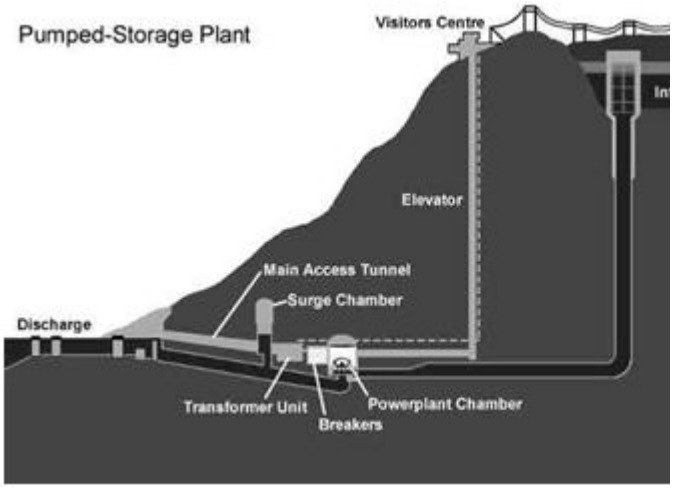

Figure 8: PHES

50	90	3000	3000	30	
50	94.9	4000	100k	High	
30	95	1000	>125,000	High	
30	95	Very high	-	Negligible	
30	50	Fair	40 years	Negligible	
.3	80	-	75years	Negligible	

3. Conclusion

ESS is a very important term to full fill the requirement of electricity, in this paper we analysis all type of storage system and discussed accordingly. And wee se that the pumped hydroelectric storage system is most efficient of others. and we study that energy can be stored in long and short duration. The need of energy storage system is that in smart grid because in off peak demand load hour it helps to full fill the criteria of the electricity. The design of the smart grid of this type is take an advantages to full fill the energy requirement. In this paper we study about the all type of energy storage system.

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	Energy density	Energy efficiency	Power density	Life time	Self- discharge	Environmental effect

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