**Unit-II**

Role of GIS in smart grid

GIS will **define and maintain more accurate, complete network models and be an integral part of new Outage Management (OMS) and Advanced Distribution Management Systems (ADMS)**. GIS will provide the geographical organizational aspects of Business Intelligence (BI) and Data Analytics (DA) capabilities.

**The Role of GIS in the Smart Grid**

Many factors are changing the way our energy networks operate: regulatory agencies, the rise of renewable energy sources, and smart technologies that drive intelligent devices in the home or along the network. As the electrical power grid grows ever smarter, these developments are causing organizations to take a closer look at the technologies that support the management and operation of the network.  
  
Up to now, energy networks have been a one-way channel from generation to consumption, but emerging technologies that enable two-way communications are creating the possibility of a dialogue between the consumer and the supplier. This results in a consumer who knows in real time how much power they are using (and at what cost), and a utility that has better management, pricing, and forecasting tools for its network.  
  
It also blurs the distinction between consumer and provider, enabling the customer to become an occasional supplier as local generation facilities and the use of electric vehicle batteries for load-balancing storage become a reality. Manufacturing businesses may even find themselves making minute-by-minute decisions about switching on their generators, either to send power to their factories, or to sell it to the grid.

An acronym for **Intelligent Electronic Device**. An IED, as it relates to the protection and power system automation industry, is a device that performs electrical protection functions, advanced local control intelligence, has the ability to monitor processes and can communicate directly to a SCADA system.

IEDs receive data from [sensors](https://en.wikipedia.org/wiki/Sensors) and power equipment and can issue control commands, such as tripping circuit breakers if they sense [voltage](https://en.wikipedia.org/wiki/Voltage), [current](https://en.wikipedia.org/wiki/Electric_current), or [frequency](https://en.wikipedia.org/wiki/Frequency) anomalies, or raise/lower tap positions in order to maintain the desired voltage level. Common types of IEDs include protective relaying devices, [tap changer](https://en.wikipedia.org/wiki/Tap_changer#On-load_designs_(OLTC)) controllers, circuit breaker controllers, capacitor bank switches, recloser controllers, voltage regulators etc. This is generally controlled by a setting file. The testing of setting files is typically one of the most time-consuming roles of a protection tester.

IED's play in today's power networks. They are used for **protection purposes, power quality analysis, network monitoring, energy metering**. They have to be equipped with transmission protocols that are used in substation automation like IEC 61850.

IEDs are used as a more modern alternative to, or a complement of, setup with traditional [remote terminal units](https://en.wikipedia.org/wiki/Remote_terminal_unit) (RTUs). Unlike the RTUs, IEDs are integrated with the devices they control and offer a standardized set of measuring and control points that is easier to configure and require less wiring. Most IEDs have a communication port and built-in support for standard communication protocols ([DNP3](https://en.wikipedia.org/wiki/DNP3), [IEC104](https://en.wikipedia.org/wiki/IEC104) or IEC61850), so they can communicate directly with the [SCADA](https://en.wikipedia.org/wiki/SCADA) system or a substation [programmable logic controller](https://en.wikipedia.org/wiki/Programmable_logic_controller). Alternatively, they can be connected to a substation RTU that acts as a gateway towards the SCADA server

#### Battery storage

One such technology is Battery Energy Storage Systems (BESS). A smart grid encourages integration of more and more power from renewable energy based sources. However, as sunlight and wind are intermittent during the day, power generation from these sources would pose some operational challenges. Hence, a smoothening mechanism is required to ensure reliable and quality power supply to consumers. The BESS will essentially absorb excess power from the sun during solar hours (if demand is less during that period) and store it to supply during peak demand periods, in a way restoring balance in the system by time-shifting of energy.

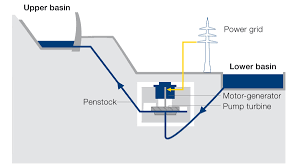
Installing BESS at the local substation level, from where supply goes to individual households, is an option for successful implementation of a smart distribution grid. These installations will also help reduce the stress on local transformers and enhance their operational life by supplying energy stored in the battery during periods of high electricity demand, thus reducing load on the transformers. Research is underway to find the optimal size of such batteries and to find the best strategies to operate them for various applications at the distribution network level. One such unique initiative, called UI-ASSIST, has been launched recently by the governments of India and the United States of America.

**SMES:**

Superconducting magnetic energy storage (SMES) technology has been progressed actively for use in modern power system. Principal application schemes of a sole SMES system, a hybrid energy storage system (HESS) consisting of small-scale SMES and other commercial energy storage systems (ESSs), a distributed SMES (DSMES) system, and a distributed HESS (DHESS) are presented and compared. The concept of the SMES-based HESS provides an economical way to apply medium-scale SMES systems in daily load leveling and to apply small-scale SMES systems in power quality improvement. A dc power distribution network case with superconducting dc cables and SMES devices is conceptually designed to evaluate the performance of the proposed four SMES application schemes. The results show that the novel concept of the SMES-based DHESS can be particularly expected to achieve efficient and economical power management. Finally, the application prospects and possible schemes implanting SMES devices for power generation, transmission, distribution and utilization are explored for use in future smart grid.

**Pumped-storage hydroelectricity** (**PSH**), or **pumped hydroelectric energy storage** (**PHES**), is a type of [hydroelectric](https://en.wikipedia.org/wiki/Hydroelectricity) [energy storage](https://en.wikipedia.org/wiki/Energy_storage) used by [electric power systems](https://en.wikipedia.org/wiki/Electric_power_system) for [load balancing](https://en.wikipedia.org/wiki/Load_balancing_(electrical_power)). The method stores energy in the form of [gravitational potential energy](https://en.wikipedia.org/wiki/Gravitational_potential_energy) of water, pumped from a lower elevation [reservoir](https://en.wikipedia.org/wiki/Reservoir) to a higher elevation. Low-cost surplus off-peak electric power is typically used to run the pumps. During periods of high electrical demand, the stored water is released through [turbines](https://en.wikipedia.org/wiki/Water_turbine) to produce electric power. Although the losses of the pumping process make the plant a net consumer of energy overall, the system increases [revenue](https://en.wikipedia.org/wiki/Revenue) by selling more electricity during periods of [peak demand](https://en.wikipedia.org/wiki/Peak_demand), when electricity prices are highest. If the upper lake collects significant rainfall or is fed by a river then the plant may be a net energy producer in the manner of a traditional hydroelectric plant.

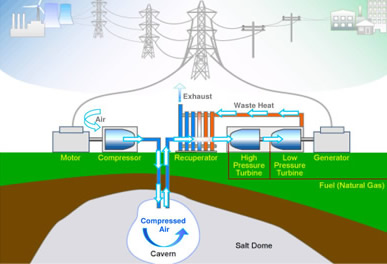
Pumped-storage hydroelectricity allows energy from [intermittent sources](https://en.wikipedia.org/wiki/Intermittent_energy_source) (such as [solar](https://en.wikipedia.org/wiki/Solar_power), [wind](https://en.wikipedia.org/wiki/Wind_power)) and other renewables, or excess electricity from continuous base-load sources (such as coal or nuclear) to be saved for periods of higher demand.[[1]](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-1)[[2]](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-2) The reservoirs used with pumped storage are quite small when compared to conventional hydroelectric dams of similar power capacity, and generating periods are often less than half a day.



Pumped storage is by far the largest-capacity form of [grid energy storage](https://en.wikipedia.org/wiki/Grid_energy_storage) available, and, as of 2020, the [United States Department of Energy Global Energy Storage Database](https://en.wikipedia.org/wiki/United_States_Department_of_Energy_Global_Energy_Storage_Database) reports that PSH accounts for around 95% of all active tracked storage installations worldwide, with a total installed throughput capacity of over 181 [GW](https://en.wikipedia.org/wiki/Gigawatt), of which about 29 GW are in the United States, and a total installed storage capacity of over 1.6 [TWh](https://en.wikipedia.org/wiki/Kilowatt-hour" \o "Kilowatt-hour), of which about 250 GWh are in the United States.[[3]](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-3) The *round-trip* [energy efficiency](https://en.wikipedia.org/wiki/Energy_conversion_efficiency) of PSH varies between 70%–80%,[[4]](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-EconomistPSH-4)[[5]](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-thier-5)[[6]](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-Levine-6)[[7]](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-yang-7) with some sources claiming up to 87%.[[8]](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-heco-8) The main disadvantage of PSH is the specialist nature of the site required, needing both geographical height and water availability. Suitable sites are therefore likely to be in hilly or mountainous regions, and potentially in areas of natural beauty, making PSH susceptible to social and ecological issues. Many recently proposed projects, at least in the U.S., avoid highly sensitive or scenic areas, and some propose to take advantage of "brownfield" locations such as disused mines.[[](https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity#cite_note-9)

**Compressed-air energy storage** (CAES) is a way to [store energy](https://en.wikipedia.org/wiki/Energy_storage) for later use using [compressed air](https://en.wikipedia.org/wiki/Compressed_air). At a [utility](https://en.wikipedia.org/wiki/Public_utility) scale, energy generated during periods of low demand can be released during [peak load](https://en.wikipedia.org/wiki/Peak_load) periods.[[1]](https://en.wikipedia.org/wiki/Compressed-air_energy_storage#cite_note-NYT-2010.07.28-1)

The first utility-scale CAES project has been built in Huntorf, Germany, being still operational.[[2]](https://en.wikipedia.org/wiki/Compressed-air_energy_storage#cite_note-2) While the Huntorf CAES plant was initially developed as a load balancer for [fossil fuel-generated electricity](https://en.wikipedia.org/wiki/Fossil_fuel_power_station), the global shift towards [renewable energy](https://en.wikipedia.org/wiki/Renewable_energy) has led to a renewed interest in CAES systems,[[3]](https://en.wikipedia.org/wiki/Compressed-air_energy_storage#cite_note-3) to help highly intermittent energy sources like [photovoltaics](https://en.wikipedia.org/wiki/Photovoltaics" \o "Photovoltaics) and [wind](https://en.wikipedia.org/wiki/Wind_power) satisfy fluctuating electricity demands.[[4]](https://en.wikipedia.org/wiki/Compressed-air_energy_storage#cite_note-The_role_of_compressed_air_energy_storage_(CAES)_in_future_sustainable_energy_systems.-4)



One ongoing challenge in large-scale CAES design is the management of thermal energy since the compression of air leads to an unwanted [temperature increase](https://en.wikipedia.org/wiki/Joule-Thompson_effect) that not only reduces operational efficiency but can also lead to damage. The main difference between various CAES architectures lies in thermal engineering. On the other hand, small-scale systems have long been used as propulsion of [mine locomotives](https://en.wikipedia.org/wiki/Fireless_locomotive). Contrasted with traditional batteries, CAES systems can store energy for longer periods of time and have less upkeep.

A **phasor measurement unit** (PMU) is a device used to estimate the magnitude and phase angle of an electrical [phasor](https://en.wikipedia.org/wiki/Phasor" \o "Phasor) quantity (such as voltage or current) in the [electricity grid](https://en.wikipedia.org/wiki/Grid_(electricity)) using a common time source for synchronization. Time synchronization is usually provided by GPS or IEEE 1588 [Precision Time Protocol](https://en.wikipedia.org/wiki/Precision_Time_Protocol), which allows synchronized real-time measurements of multiple remote points on the grid. PMUs are capable of capturing samples from a waveform in quick succession and reconstructing the phasor quantity, made up of an angle measurement and a magnitude measurement. The resulting measurement is known as a **synchrophasor**. These time synchronized measurements are important because if the grid’s supply and demand are not perfectly matched, frequency imbalances can cause stress on the grid, which is a potential cause for power outages.[[1]](https://en.wikipedia.org/wiki/Phasor_measurement_unit#cite_note-1)

PMUs can also be used to measure the frequency in the power grid. A typical commercial PMU can report measurements with very high temporal resolution, up to 120 measurements per second. This helps engineers in analyzing dynamic events in the grid which is not possible with traditional [SCADA](https://en.wikipedia.org/wiki/SCADA) measurements that generate one measurement every 2 or 4 seconds. Therefore, PMUs equip utilities with enhanced monitoring and control capabilities and are considered to be one of the most important measuring devices in the future of power systems.[[2]](https://en.wikipedia.org/wiki/Phasor_measurement_unit#cite_note-2) A PMU can be a dedicated device, or the PMU function can be incorporated into a [protective relay](https://en.wikipedia.org/wiki/Protective_relay) or other device.