ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY

AUTONOMOUS INSTITUTION

Approved by AICTE & Affiliated to Anna University
NBA Accredited for BE (ECE, EEE, MECH) | Accredited by NAAC with A+ Grade
Anjugramam - Kanyakumari Main Road, Palkulam,Variyoor P.O. - 629 401, Kanyakumari District.

CAI 335 : SOLAR AND WIND ENERGY SYSTEMS

UNIT 5

ALTERNATE ENERGY SOURCES

Prepared by:

Mr.Arunpandian.N.

Assistant Professor

Department of Agricultural Engineering

Geothermal Energy and Resources: An In-Depth Explanation

Geothermal energy is the energy derived from the heat stored beneath the Earth's surface. This heat comes from two primary sources: the natural radioactive decay of elements within the Earth's interior and the heat leftover from the planet's formation. Geothermal energy has been used for thousands of years for bathing, heating, and cooking, and today, it is harnessed to generate electricity and provide heating and cooling systems for homes and businesses.

How Geothermal Energy Works

Geothermal energy relies on the heat from the Earth's interior. The Earth's crust, mantle, and core contain immense amounts of heat, and this heat is continually transferred to the surface. The heat beneath the Earth's surface is accessed through drilling, similar to how oil or gas is extracted, but instead of extracting fossil fuels, it taps into the heat or geothermal resources to generate power or provide heating.

The process of utilizing geothermal energy involves capturing the heat from hot rocks, steam, or water deep inside the Earth and converting it into useful forms of energy.

There are **three main types of geothermal resources** that can be used for energy production:

1. **Dry Steam Resources**:
   - These are the oldest and simplest types of geothermal systems. Dry steam directly accesses steam reservoirs from the Earth's crust, which is then used to drive turbines for power generation.
   - **Example**: The **Geysers** in California, USA, is the largest dry steam geothermal field in the world.
2. **Wet Steam (Hot Water) Resources**:
   - Wet steam or hot water geothermal resources consist of water that is heated by the Earth's internal heat. The water is often found in deep underground reservoirs. The hot water is brought to the surface, where it can either be used for direct heating or converted into steam to turn turbines for electricity generation.
   - **Example**: **The Blue Lagoon** in Iceland uses geothermal water for heating and is a source of tourism.
3. **Geopressured Resources**:
   - These are underground reservoirs where the geothermal heat is combined with high-pressure water and gas. The high pressure allows the water to remain in liquid form, even at high temperatures.
   - **Geopressured resources** are not yet widely used but are seen as potential sources of energy in the future.
   - **Example**: Some areas in the Gulf Coast of the USA have been identified as having geopressured resources.

Geothermal Energy Resources

Geothermal resources can be classified into **shallow resources** and **deep resources**, based on their depth and temperature:

1. **Shallow Geothermal Resources**:
   - These are the resources located close to the Earth's surface, often within a few kilometers, and are typically used for **direct heating** and **cooling** applications (e.g., geothermal heat pumps).
   - Shallow geothermal systems can harness the relatively consistent temperature of the Earth just below the surface, making them ideal for space heating and cooling in buildings.
   - **Geothermal Heat Pumps**: These are closed-loop systems where a fluid circulates through underground pipes (usually in the shallow soil or bedrock) and absorbs the Earth's heat. The heat is then transferred into buildings for space heating in winter and cooling in summer.
     - **Advantages**: Energy-efficient and reliable for heating and cooling needs.
     - **Disadvantages**: Limited to relatively small-scale applications (residential or commercial).
2. **Deep Geothermal Resources**:
   - These are located much deeper within the Earth (several kilometers underground). These deep resources are typically used for **electricity generation** or **district heating**.
   - **Hot Dry Rock** and **Geothermal Reservoirs**: These geothermal resources can be accessed by drilling into the Earth's crust to tap into hot rock formations that can generate steam or hot water.
   - **Enhanced Geothermal Systems (EGS)**: EGS are engineered reservoirs created by fracturing rock formations to enhance permeability and allow for the circulation of fluids through the rocks to extract heat. This allows geothermal energy extraction from areas that are not naturally conducive to geothermal production.
   - **Example**: The **Salton Sea Geothermal Field** in California is one of the largest deep geothermal resources in the world, producing significant amounts of electricity.

Geothermal Power Plants

Geothermal power plants convert geothermal energy into electrical power. These plants work by using steam or hot water from the Earth's interior to turn turbines that generate electricity. There are several types of geothermal power plants, depending on the temperature and characteristics of the geothermal resources they utilize.

1. Dry Steam Plants

- **How they work**: Dry steam plants use steam directly from geothermal reservoirs to turn turbines. The steam is sent directly to a turbine, which generates electricity. Once the steam passes through the turbine, it is condensed back into water and injected back into the reservoir to be reheated.
- **Example**: The **Geysers** geothermal field in California is a dry steam plant that generates a significant portion of the electricity in California.

2. Flash Steam Plants

- **How they work**: Flash steam plants use water from geothermal reservoirs that are under high pressure. When the pressure is decreased (flashed), part of the water instantly turns into steam. This steam is used to turn turbines.
- **Process**: The hot water is brought to the surface and then pressure is reduced, causing the water to flash into steam. The steam drives the turbine to generate electricity.
- **Example**: **The Cerro Prieto Geothermal Power Station** in Mexico is one of the largest flash steam plants in the world.

3. Binary Cycle Power Plants

- **How they work**: Binary cycle plants operate at lower temperatures than dry steam and flash plants. They transfer heat from geothermal hot water to another liquid that has a low boiling point. This second liquid is vaporized in a heat exchanger and used to turn the turbine.
- **Advantages**: These plants can operate with lower temperature geothermal resources (between 57–182°C). They are more flexible and can be installed in a variety of locations with less impact on the environment.
- **Example**: **The Nesjavellir Geothermal Power Station** in Iceland is a binary cycle plant.

Applications of Geothermal Energy

1. **Electricity Generation**:
    - Geothermal power plants are the most common method for generating electricity from geothermal energy. These plants can produce large-scale electricity, and they are typically located near geothermal reservoirs with high-temperature resources.
    - **Example**: The **Hellisheiði Geothermal Power Station** in Iceland generates over 300 MW of electricity.
2. **Direct Heating and Cooling**:
    - Geothermal energy can be used directly to heat buildings, greenhouses, aquaculture ponds, and industrial processes.

   - In many regions, hot springs have been used for centuries to heat buildings and water.
   - **Geothermal District Heating**: In countries like Iceland, geothermal energy is used in district heating systems to provide heat for entire cities.
3. **Geothermal Heat Pumps**:
   - As mentioned earlier, geothermal heat pumps are used in buildings for heating and cooling. These systems take advantage of the Earth's stable temperature just below the surface to provide energy-efficient heating in the winter and cooling in the summer.
4. **Agricultural and Industrial Applications**:
   - Geothermal energy can also be used for drying crops, pasteurizing milk, or other industrial processes that require low-temperature heat. Greenhouses can be heated with geothermal energy to extend growing seasons.

Advantages of Geothermal Energy

- **Renewable**: Geothermal energy is renewable as long as the Earth's internal heat is available. Unlike fossil fuels, geothermal resources are not at risk of being depleted over time.
- **Low Environmental Impact**: Geothermal power plants typically produce minimal carbon emissions and have less impact on the environment compared to fossil fuel-based energy plants.
- **Baseload Power**: Geothermal power plants can operate 24/7, unlike solar or wind energy, which are intermittent. This makes geothermal energy a reliable and consistent source of power.
- **Small Land Footprint**: Geothermal plants have a small land footprint compared to other renewable energy plants like solar farms or wind farms.
- **Economic Benefits**: Geothermal energy can help reduce dependence on imported fossil fuels, create jobs, and stimulate local economies, especially in regions rich in geothermal resources.

Challenges of Geothermal Energy

- **Location-Specific**: Geothermal energy is location-dependent. The best geothermal resources are often found in specific regions, such as volcanic areas or along tectonic plate boundaries (e.g., Iceland, California, New Zealand, and the Philippines).
- **High Initial Costs**: The upfront capital costs for building geothermal power plants and drilling geothermal wells are relatively high. The drilling process can also be technically challenging and costly.
- **Risk of Depletion**: If geothermal resources are overexploited without proper management, they can be depleted temporarily. Proper resource management and re-injection of fluids are necessary to ensure sustainability.

- **Environmental Concerns**: While geothermal energy is considered environmentally friendly, there can be some localized impacts, such as the release of trace gases like hydrogen sulfide, and the potential for land subsidence or ground disturbance.

Conclusion

Geothermal energy is a reliable, renewable, and sustainable energy source with significant potential for electricity generation, heating, and cooling. With various technologies like dry steam, flash steam, and binary cycle power plants, geothermal resources can be harnessed efficiently. Geothermal energy is not only vital for providing baseload power but also offers numerous applications in heating, cooling, and industrial processes. Despite its challenges, such as location specificity and high initial investment costs, the growing global interest in clean energy makes geothermal power a promising option for the future. As technology improves, the use of geothermal energy could expand to more regions, contributing to the global transition to renewable energy sources.

Classification and Types of Geothermal Power Plants

Geothermal power plants are facilities that convert geothermal energy into electrical power. These plants are designed based on the type of geothermal resource available and the temperature of the geothermal fluid. Geothermal power plants utilize steam or hot water from beneath the Earth's surface to turn turbines connected to generators that produce electricity. Geothermal energy is one of the most promising renewable sources of energy because it is reliable, available 24/7, and produces minimal greenhouse gas emissions.

Geothermal power plants can be classified into **three main types** based on the way they operate, the temperature of the geothermal fluid, and the method of energy conversion:

1. **Dry Steam Power Plants**
2. **Flash Steam Power Plants**
3. **Binary Cycle Power Plants**

Additionally, there are **Enhanced Geothermal Systems (EGS)**, a newer method that expands the areas where geothermal energy can be used.

---

1. Dry Steam Power Plants

Overview:

- **Dry steam power plants** are the oldest and simplest type of geothermal power plant. They use steam directly from geothermal reservoirs to drive turbines and generate electricity. These plants operate on **high-temperature geothermal resources** where steam is naturally available without the need for boiling water.

Working Principle:

- In dry steam plants, the steam from geothermal reservoirs is brought to the surface through wells. The steam is then used to rotate turbines connected to a generator, which produces electricity.
- After passing through the turbine, the steam is cooled, condensed back into water, and re-injected into the geothermal reservoir to maintain pressure and sustainability of the system.

Advantages:

- Simple technology and highly efficient for locations with naturally occurring steam.
- High efficiency in regions where steam reservoirs are abundant.
- Minimal environmental impact, especially in terms of emissions, as no additional water needs to be heated to produce steam.

Disadvantages:

- Only viable in areas with high-temperature, dry steam reservoirs, such as active geothermal fields.
- Limited in geographical distribution due to the need for specific geological conditions.

Example:

- **The Geysers** in California, USA, is the largest dry steam geothermal field in the world and produces around 1,500 MW of electricity, which is sufficient to power approximately 1.5 million homes.

---

2. Flash Steam Power Plants

Overview:

- **Flash steam power plants** are the most common type of geothermal power plant in operation today. They work by using **moderately high-temperature geothermal fluids** (water), typically in the range of 180°C to 350°C. Flash steam plants use water that is under high pressure to extract steam by rapidly decreasing the pressure (flashing), which allows the water to turn into steam. This steam is then used to generate electricity.

Working Principle:

- In flash steam plants, geothermal water is pumped from deep underground reservoirs where the water is hot and under high pressure. When the pressure is suddenly reduced (flashed), part of the water converts into steam. The steam is directed through a turbine, which drives a generator to produce electricity.
- After passing through the turbine, the steam is condensed back into water and injected back into the geothermal reservoir, making the system sustainable.

Advantages:

- **Flexibility**: Flash steam plants can operate in a range of geothermal resources, making them suitable for various geothermal sites.
- **Proven Technology**: Flash steam plants are widely used and have a long history of operational success, especially in moderate-temperature geothermal reservoirs.

Disadvantages:

- The need for high-pressure geothermal fluid means that this technology is not suitable for lower-temperature resources.
- More complex infrastructure compared to dry steam plants, as it requires systems to manage both high-pressure fluids and the steam generated after flashing.

Example:

- The **Cerro Prieto Geothermal Power Station** in Mexico is one of the largest flash steam plants in the world, generating about 720 MW of electricity.

---

3. Binary Cycle Power Plants

Overview:

- **Binary cycle power plants** are designed to utilize **low-to-moderate temperature geothermal resources**, typically in the range of 100°C to 180°C. These plants are ideal for regions where geothermal fluids are not hot enough to produce steam directly.

Working Principle:

- In binary cycle plants, geothermal water is used to heat a secondary fluid (often referred to as a working fluid) that has a lower boiling point than water. This secondary fluid is

vaporized by the geothermal water, and the vaporized fluid is used to drive a turbine connected to a generator.
- The geothermal water never mixes with the secondary fluid. After the geothermal water passes through the heat exchanger, it is typically re-injected into the ground.
- The secondary fluid, which evaporates at a lower temperature, is condensed back into liquid form in a closed loop, which can then be reheated by the geothermal fluid.

Advantages:

- **Efficiency at Lower Temperatures**: This method can be used in regions with geothermal reservoirs that have lower temperatures, allowing for more widespread use of geothermal energy.
- **Closed-Loop System**: Because the geothermal water does not mix with the secondary fluid, binary cycle plants are environmentally cleaner, with minimal emissions.
- **Flexibility**: Can be applied to many different geothermal sites, particularly where geothermal fluid is not hot enough for dry steam or flash systems.

Disadvantages:

- Lower efficiency than dry steam or flash plants, as the temperature difference between the geothermal fluid and secondary fluid is smaller.
- Requires more complex heat exchanger technology, and the cost of the secondary fluid can be higher.

Example:

- **The Nesjavellir Geothermal Power Station** in Iceland is an example of a binary cycle plant, using low-temperature geothermal resources to generate electricity.

---

4. Enhanced Geothermal Systems (EGS)

Overview:

- **Enhanced Geothermal Systems (EGS)**, sometimes referred to as **engineered geothermal systems**, are a new and evolving technology designed to expand the geographical and technical limits of geothermal energy production. EGS can be used in areas that do not have naturally occurring geothermal reservoirs but have the potential for geothermal energy extraction.

Working Principle:

- EGS works by creating artificial geothermal reservoirs in hot rock formations that are otherwise not permeable or conducive to energy extraction. This is done by injecting water into the rocks at high pressure, which fractures the rock and creates pathways for the water to flow.

- The water is then heated by the surrounding rock and pumped back to the surface, where it can be used to generate steam for electricity generation or direct heating.

Advantages:

- **Increased Potential**: EGS can be deployed in a wider range of locations, including areas where natural geothermal resources are not readily available.
- **Greater Energy Yield**: EGS has the potential to provide larger-scale, baseload power generation by tapping into deep geothermal heat sources that were previously inaccessible.

Disadvantages:

- **High Initial Costs**: Developing an EGS requires significant upfront investment for drilling, fracturing, and building infrastructure.
- **Technical Challenges**: The technology is still evolving, and there are concerns about induced seismicity (small earthquakes caused by fluid injection into the earth).
- **Environmental Impact**: The fracturing process can affect local ecosystems, and managing the re-injection of fluids remains a challenge.

Example:

- The **Salton Sea Geothermal Field** in California is being used for experimental EGS development, where deep drilling and hydraulic fracturing are used to enhance the geothermal system.

Summary of Geothermal Power Plants

Type	Temperature Range	Technology Used	Applications	Example
Dry Steam Power Plants	> 250°C	Direct steam use	High-temperature geothermal reservoirs	**The Geysers**, California, USA
Flash Steam Power Plants	180°C to 350°C	Flashing water to generate steam	Moderate-temperature geothermal reservoirs	**Cerro Prieto**, Mexico

Type	Temperature Range	Technology Used	Applications	Example
Binary Cycle Power Plants	100°C to 180°C	Heat exchanger with a secondary fluid	Low-temperature geothermal reservoirs	**Nesjavellir**, Iceland
Enhanced Geothermal Systems (EGS)	Variable (Deep)	Hydraulic fracturing to create a reservoir	Underdeveloped geothermal areas, deep rocks	**Salton Sea**, California, USA

Conclusion

Geothermal power plants are essential in harnessing the Earth's internal heat for sustainable energy production. The classification of geothermal plants into dry steam, flash steam, binary cycle, and enhanced geothermal systems reflects the various ways geothermal energy can be used depending on the temperature and availability of geothermal resources. Dry steam and flash steam plants are best suited for high-temperature reservoirs, while binary cycle plants are ideal for moderate and low-temperature sites. Enhanced Geothermal Systems, though still in development, promise to expand the use of geothermal energy by tapping into previously inaccessible heat sources.