23MCT003 – ENVIRONMENTAL SCIENCE & SUSTAINABILITY

3-RENEWABLE ENERGY SOURCES

3.5– GEOTHERMAL ENERGY - CONCEPT, ORIGIN OF POWER PLANTS

Geothermal Energy

Concept: Geothermal energy is a renewable energy source that derives heat from the Earth's internal layers. This heat is created from the natural decay of radioactive isotopes, including uranium, thorium, and potassium, as well as residual heat from the planet's formation. Geothermal energy can be used directly for heating and industrial purposes or converted to electricity using geothermal power plants.

The Earth's heat naturally moves toward the surface, and in some places, it forms geothermal hotspots where temperatures are significantly higher. These hotspots, where magma or hot water reservoirs are close to the surface, are often harnessed for energy.

How Geothermal Power Works

Geothermal power plants extract this heat from reservoirs of hot water or steam located deep within the Earth's crust. There are three main types of geothermal power plants, each designed to harness this energy efficiently based on the specific geothermal resources available:

1. Dry Steam Power Plants:
    - Concept: The oldest type of geothermal power plant, dry steam plants use underground steam directly to turn turbines connected to generators.
    - Process: The plant pipes the steam from a geothermal reservoir directly to the turbine, which then powers a generator to produce electricity. Afterward, the steam is condensed and reinjected into the ground to sustain the reservoir.
    - Example: The Geysers in California, USA, is a well-known example of a dry steam geothermal plant.
2. Flash Steam Power Plants:
    - Concept: Flash steam plants are the most common type of geothermal power plant. They are suitable for high-temperature geothermal reservoirs where water temperatures exceed 180°C (356°F).

- Process: High-pressure hot water is brought to the surface. As it reaches lower pressure, the water flashes (turns) into steam. This steam is then directed to turbines to generate electricity. Any residual water is injected back into the ground, where it can be reheated for future use.
- Example: The Makiling-Banahaw plant in the Philippines is a flash steam geothermal power plant.

3. Binary Cycle Power Plants:
    - Concept: Binary cycle plants are ideal for moderate-temperature geothermal sources (between 100–180°C or 212–356°F). Unlike the other types, binary plants don't use steam directly from geothermal reservoirs but instead transfer heat to another fluid with a lower boiling point.
    - Process: Hot geothermal fluid heats a secondary, organic working fluid (like isobutane) with a lower boiling point. The working fluid vaporizes, drives the turbine, and powers the generator. The geothermal fluid is then reinjected, creating a closed-loop system with minimal emissions.
    - Example: Chena Hot Springs in Alaska, USA, uses a binary cycle power plant to generate electricity from lower-temperature geothermal resources.

Origin of Geothermal Power Plants

The history of geothermal energy for electricity generation began in the early 20th century. Here’s a look at the development of geothermal power plants:

1. Italy (1904):
    - The world’s first geothermal power plant was established in Larderello, Italy. Italian scientist Piero Ginori Conti successfully demonstrated the use of geothermal steam to generate electricity, powering five light bulbs in 1904.
    - By 1911, the Larderello plant had grown to become the first commercial-scale geothermal power plant, generating electricity for the town and surrounding areas.
2. United States (1960):
    - The U.S. entered the geothermal energy scene with the development of the first geothermal power plant in The Geysers, California. Initially producing just 11 MW of power, The Geysers has grown to be one of the largest geothermal fields in the world, with an installed capacity of over 900 MW.

- The success of The Geysers paved the way for geothermal development in other parts of the country, especially in California, Nevada, and Hawaii.

3. New Zealand (1958):
   - New Zealand built its first geothermal power plant in Wairakei. This plant was unique because it used a flash steam system, and it remains operational today, contributing significantly to New Zealand's energy grid.
   - New Zealand’s geothermal development showcased the potential for geothermal energy in volcanic regions and led to further exploration of geothermal resources in similar areas.
4. Philippines, Iceland, and Japan (1970s):
   - The Philippines, Iceland, and Japan also began harnessing geothermal power in the 1970s as oil prices rose and interest in alternative energy sources grew. These countries now rely significantly on geothermal energy to meet their power needs.
   - Iceland, in particular, leverages its abundant geothermal resources to generate electricity and provide district heating, achieving nearly 90% of its heating needs through geothermal sources.
5. Global Expansion (2000s–Present):
   - Geothermal power plants have been developed worldwide, including in Indonesia, Kenya, Turkey, and other geothermal-rich regions. With advancements in binary cycle technology, geothermal power has expanded to areas with lower temperature resources, making it accessible to a broader range of countries.

Advantages and Disadvantages of Geothermal Energy

Advantages:

1. Renewable and Sustainable: Geothermal energy is replenished by the Earth’s heat, making it a sustainable energy source.
2. Low Emissions: Geothermal plants emit minimal greenhouse gases, mainly water vapor, and can significantly reduce carbon footprints.
3. Baseload Power: Unlike wind or solar, geothermal energy provides continuous power output, which supports grid stability and reliability.
4. Small Land Footprint: Geothermal plants require relatively little land compared to solar or wind farms, making them suitable for smaller areas.

5. Long Lifespan: Properly managed geothermal plants can operate for decades, providing reliable power over a long period.

Disadvantages:

1. High Initial Costs: The initial drilling and infrastructure costs for geothermal plants are high, as geothermal reservoirs can be deep and challenging to access.
2. Location-Specific: Geothermal energy is most feasible in areas with volcanic activity or tectonic plate boundaries, which limits its global availability.
3. Risk of Depletion: Poorly managed geothermal reservoirs can cool down over time, reducing efficiency and energy output.
4. Environmental Concerns: Geothermal plants can release trace amounts of gases, like hydrogen sulfide, and pose a risk of induced seismic activity (earthquakes) due to drilling.
5. Water Usage: Geothermal plants often require large amounts of water for cooling and injection, which can strain local water resources in arid regions.

Examples of Geothermal Energy Development in India

India has significant geothermal potential, particularly in the Himalayas, western coastal regions, and other tectonically active areas. The government has identified several potential sites, and projects are being developed to explore and utilize geothermal energy.

1. Puga Valley, Ladakh:
   - Puga Valley is located in the Himalayan region and is estimated to have a geothermal resource temperature between 240–260°C. The area has fumaroles, hot springs, and mud pools, making it a prime site for geothermal exploration.
   - The Indian government, in partnership with ONGC and other organizations, has developed a pilot project in Puga Valley to tap into geothermal energy.
2. Tattapani, Chhattisgarh:
   - Tattapani has geothermal springs with temperatures reaching up to 98°C. This site has been explored for geothermal potential, and preliminary studies suggest it could support electricity generation and direct heating applications.
3. Manikaran, Himachal Pradesh:
   - Known for its hot springs, Manikaran has been evaluated for geothermal energy production, with plans to use the energy for local heating and potential electricity generation.

Need for Future Development of Geothermal Energy in India

Geothermal energy in India has considerable potential to support the country's renewable energy goals and reduce dependency on fossil fuels. Here's why further development is essential:

1. Energy Diversification: Geothermal can provide an additional renewable resource, diversifying India's energy mix and enhancing energy security.
2. Reliable Power for Remote Areas: Geothermal plants can support remote and mountainous regions that may struggle to access consistent electricity from the grid.
3. Reduced Environmental Impact: As a low-emission energy source, geothermal aligns well with India's climate commitments under the Paris Agreement.
4. Local Economic Development: Developing geothermal plants can create jobs and support local economies, especially in underdeveloped areas with geothermal potential.
5. Research and Development: Continued investment in R&D can help India improve drilling technology, reduce costs, and expand geothermal feasibility in lower-temperature areas.

Conclusion

Geothermal energy offers a clean, reliable, and sustainable energy source with potential to support India's growing energy needs and climate goals. By leveraging high-potential sites and investing in geothermal technology, India can create a more diverse and resilient energy system for a sustainable future.