Limaçon Technology in Power Generation

Subjects: Energy & Fuels

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Limaçon rotary machines are the heart of power generation systems, especially small- and micro-scale ones. These machines are the prime movers that play the main role in converting the potential energy to other useful forms of work, such as mechanical and/or electrical; the generated energy can also be stored in batteries or in the form of hydrogen. The focus of this paper is on the working of this limaçon technology, and the embodiments and mechanical drives to produce the unique motion of these machines. This paper will also discuss the related power-generating cycles and control schemes.

power generation cycles rotary machine prime mover expander limaçon technology control system

Introduction

Power generation systems, in general, convert either heat or pressure, both of which are potential energy, to mechanical work that can be directly utilised or converted to electricity and/or other forms of energy storage [1]. Power generation can be divided into large-, medium-, and small-scale systems depending upon their nominal output; however, definitions for the exact ranges of these categories vary. Large- and medium-scale systems are widely adopted in centralised power generation plants and are generally more efficient compared to smaller-scale ones. The representations of these plants are thermal-based power generation plants, or a series of interconnected plants, that supply electricity to a city or region. Being large with huge system inertia hinders these systems from responding and adapting quickly to load variations and fluctuations. These systems will need extra time to adapt to the change in load demand. Due to the centralised nature of these systems, generated electricity has to be stepped up, transported via the transmission lines, and then stepped down at the consumer end. The extra facilities and costly implementation are not suitable and cost-effective for regional and remote areas.

Small-scale power generation systems, on the other hand, are more versatile and can come in various scales to suit the size required by the end-users from one household to multiple connected households. These small-scale power plants can utilise different types of resources, both renewable and non-renewable, and employ various technologies with the same end output of generating electricity [2]. On top of that, the most important advantage of these small-scale systems over the larger candidates is their ability to be implemented as low-grade-heat- or waste-heat-recuperation systems to improve the efficiencies of current industrial processes and/or medium- and large-scale systems [3].

Generally, the generated electricity via recuperation is sold back to the grid or used directly for on-site applications; however, intermittent supply of the resource means electricity output is also intermittently generated. This is not ideal and hinders small- and micro-scale plants from being extensively adopted. There are, mainly, two solutions to this problem. The system designer has to include some storage capacity to capture the resource before using it to generate electricity. An alternative is to charge up batteries or produce hydrogen from the generated electricity and then store it. The latter approach opens up more storage capacity with less long-term environmental impact of the current battery technology.

In recent years, hydrogen generation and usage have gained traction globally. This opens up a new opportunity for small- and, especially, micro-scale (∼5–10 kW) plants to tap into the intermittent energy sources that were previously overlooked. This coupled with the flexibility and scalability of small- and micro-scale plants is an ideal combination for various industries to improve their process efficiencies and at the same time reduce their overall carbon footprint.

Power generation systems generally follow a thermodynamic cycle, e.g., Carnot Cycle, Rankine Cycle (RC), Organic Rankine Cycle (ORC), or Otto Cycle, and comprise heat exchangers, expanders or prime movers, and pumps and often utilise a working fluid to help to transport the heat within the system [1]. The system exchanges heat with the hot (higher temperature) and cold (lower temperature) sources via the heat exchangers; these are often called an evaporator (or boiler in certain applications) and condenser, respectively. The heat absorbed and rejected by the evaporator and condenser is circulated within the system with help from the pump and the working fluid. The working fluid absorbs heat from the evaporator and changes its internal energy stage, the energy-carrying fluid is transported to the expander at which most of the energy is extracted, and the excess energy is then handed over to the cold source via the condenser. Then, the fluid enters the pump and starts circulating in the system over again.

Expanders play a vital role in these power generation systems. The system's efficiency highly depends on the expander's effectiveness in converting the internal energy of the working fluid to useful work. This also depends on the suitability of the expander to the thermodynamic cycles based on which the power generation system is built [4].

This paper aims to introduce the thermodynamics cycles in Section 2, based on which power generation plants are developed. Then, the main components of these power plants are introduced and there is a focus on the heat exchangers and prime movers in Section 3. Various control strategies that can be implemented to improve the efficiency of the power system and help the system respond to changes in the operating conditions are discussed in Section 4. Section 5 discusses the advantages and drawbacks of these technologies and their potential and applications.

References

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