Multi-Energy Complementary Distributed Energy Supply Integrated Experimental System

Xianliang Yang*, Jiangjiang Wang
Department of Energy and Power Engineering, North China Electric Power University, Baoding, Hebei, China.
**Corresponding Author.*

Abstract: The equipment and system components of the multi-energy complementary distributed energy supply system are introduced, and the functions of the experimental system are briefly described. Through the experiment, students master the thermal performance and power generation performance variation of solar water heating system and solar and natural gas complementary combined cooling, heating and power supply system.

Keywords: Distributed Energy Supply System; Solar Hot Water System; Performance Variation

1. Introduction

In recent years, based on the endowment of energy resources and the demand for efficient, green, and low-carbon development, China has carried out a lot of basic work in natural gas utilization, new energy development, reform of the supply side of electric energy, distributed energy multi-generation, multi-energy complementarity, and smart energy.[1-4] 。 However, it is difficult to promote the use of this system independently because the design capacity is not suitable for selection and it is difficult to match the cooling, heating and power loads simultaneously. Hajabdollahi et al [5] established the relationship between performance and partial load rate for a CCHP system with steam turbine, internal combustion engine and diesel engine as the driving source, and optimized the system under different loads. Stanek et al [6] conducted a thermal-ecological cost analysis of a distributed energy supply system based on an internal combustion engine as the main power source, supplemented by solar photovoltaic power generation, using the cylinder liner water of the internal combustion engine to provide domestic hot water and driving an absorption chiller, and compared it with the conventional thermal-economic analysis to propose an optimization strategy for the combined supply system; Goyal et al [7] targeted a single-cylinder four-stroke water-cooled constant speed diesel engine waste heat Goyal et al [8] studied the energy utilization efficiency and fire efficiency of four modes, namely, simple power generation, cold-heat power, thermoelectric power, and cold power, using experimental and simulation methods, and the results showed that the system performed best in the cold-heat power and thermoelectric power modes; Fang et al [8] proposed a complementary configuration combining CCHP system with organic rankine cycle (ORC) (CCHP- ORC) in a complementary configuration and conducted a hypothetical case study of a Beijing hotel using Energyplus to simulate the typical daily cooling, heating, and power demand for four seasons, and the results showed that electric cooling was mainly applied in summer and ORC was mainly applied in the other three seasons, and the CO2 emissions and operating costs of primary energy consumption were better than those of the conventional CCHP system.

At present, the development of a multi-energy complementary distributed energy supply system is in its initial stage in China. The National Development and Reform Commission and the National Energy Administration promulgated the "Implementation Opinions on Promoting the Construction of Multi-energy Complimentary Integration and Optimization Demonstration Project" as well as the Ministry of Human Resources and Social Security launched several periods of "Distributed Energy Planner" job competence training. To meet the experimental requirements and practical teaching of building environment and energy application engineering and energy power majors and optimize the cultivation of innovative talents, our university designed and built a comprehensive multi-energy complementary distributed energy supply experimental system by itself. This experimental system can carry out experimental research in various aspects including gasification, power generation, heat exchange, and energy storage, providing a development platform for cultivating the comprehensive practical innovation ability of talents.

2. Experimental System Design

2.1 Experimental System Composition

The experimental system consists of LNG gasification system, internal combustion engine power generation system, solar heat collection system, heat storage system, waste heat exchange system and intelligent control platform. The experimental system is shown in Figure 1, and some of the physical drawings are in Figure 2.

The multi-energy complementary distributed energy supply comprehensive experimental system uses internal combustion engine as the driving power generation device, solar heat collection as the thermal supplement subsystem, LNG storage tank and gasification subsystem as the air source, and integrated heat storage water tank to achieve electric heating matching regulation. The system can realize the functions of solar heat collection performance test, heat storage performance test, natural gas power generation performance test, LNG gasification performance test, etc. It can provide practical teaching and scientific research activities for energy and power engineering, built environment and energy application engineering.

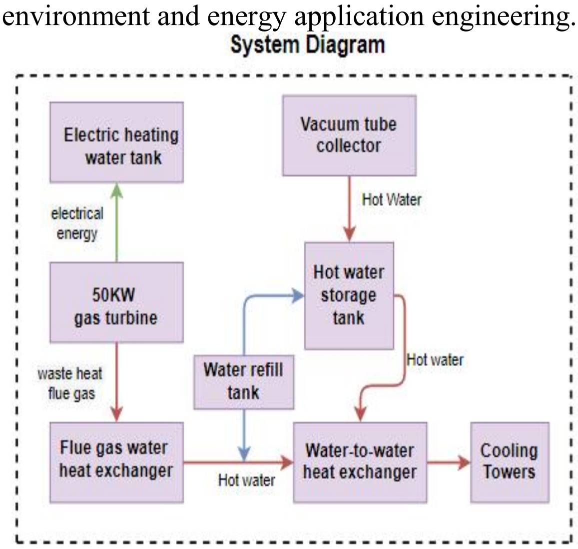

Figure 1. Distributed Energy Supply System

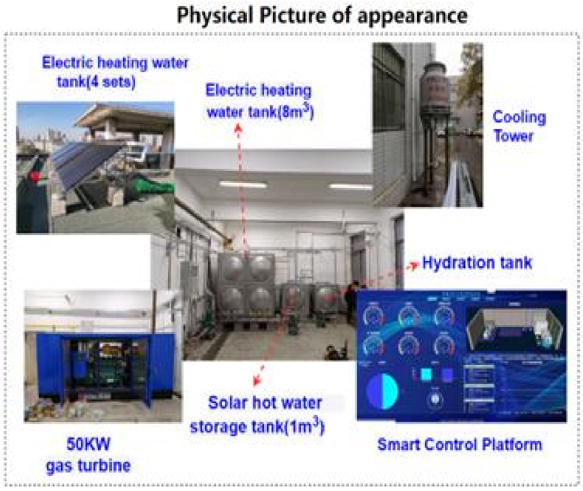

Figure 2. Distributed Energy Supply Systemin a Physical View

2.2 Experimental Project

This experimental system carries out the system-wide experiments and equipment sub-system experiments as shown in the table below. In addition to the development of single experiments, it can also provide an experimental platform for undergraduate students to conduct comprehensive and innovative experiments and improve the comprehensive practical and innovative ability to cultivate talents.

Table 1: Experiments Conducted on the Multi-Energy Complementary Distributed Energy Supply System Experimental Platform

Experimental projects	Name of undergraduate experiments that can be completed
Distributed Energy Supply System Integrity Experiment	Natural gas combined cooling, heating, and power system performance test
	Performance experiments of the solar-gas complementary distributed energy supply system
	Performance experiments of distributed energy supply system based on the solar thermal collection
	Distributed energy supply system coordinated control experiment
	Energy conversion sensible heat and latent heat exchange experiment
Subsystem performance experiments	Internal combustion engine power generation performance experiments
	Solar Collector Performance Experiment

	Solar LNG gasification performance experiment
	Thermal storage and release performance measurement experiment
	Heat exchanger thermal transfer efficiency measurement experiment

3. Periment Content

3.1 Performance Experiment of Natural Gas Cogeneration System

The natural gas cogeneration system uses natural gas as the main fuel to drive the internal combustion engine to run, and the electricity generated meets the electricity demand of the electricity-consuming equipment. The energy utilization efficiency is increased from about 40% to 80% in conventional power generation systems, saving a lot of primary energy.

3.2 Performance Experiment of the Solar-Gas Complementary Distributed Energy Supply System

Electricity from the internal combustion engine generator set heats the cold water in the storage tank through the electric heater, while the high-temperature flue gas from the generator set is recovered through the heat recovery device (gas (water) - water heat exchanger); the hot water generated by the vacuum tube solar collector enters the solar storage tank through the pipeline; the hot water from the solar storage tank and gas - water heat exchanger After the water-water heat exchanger is passed to the user side of the circulating water, and then sent by the cooling water pump to the outdoor cooling tower for cooling. The user heat load is provided by the high-temperature flue gas from the internal combustion engine, electrical energy, and solar energy. Due to the fluctuating demand on the load side, water storage tanks are used as auxiliary equipment, which can break the rigid condition of "heat-determined electricity" in CHP units and improve the stability and flexibility of the multi-energy complementary combined heat and power system.

3.3 Solar Collector Performance Experiment

The main physical parameters of temperature, flow rate, wind speed, and solar irradiance are collected in the solar collector thermal performance test experiment, converted from analog to digital with the help of A/D converter, and then transmitted to the computer control platform through the serial port, and the computer completes the automatic calculation and storage of the data, and finally generates the curve to express.

3.4 Internal Combustion Engine Power Generation Performance Experiments

In the distributed energy supply system, the generator set usually operates under partial load, and the heat recovery efficiency of the waste heat during its variable operating conditions has a large impact on the comprehensive performance of the distributed energy supply system. The waste heat of the internal combustion engine in this system is divided into two parts: one part is the waste heat of the cylinder liner cooling water, which is the heat that needs to be taken away by the cooling system to ensure the normal working temperature of the gas internal combustion engine, and the other part is the waste heat of the flue gas, which is the heat carried by the flue gas after the work of fuel combustion, and the flue gas temperature is basically between the micro and small gas turbine units. In this experimental system, the waste heat of cylinder liner cooling water and flue gas waste heat is recovered by heat recovery device and sent to heat users. The relationship between the unit load factor and the power generation (thermal) efficiency is shown in Figure 3.

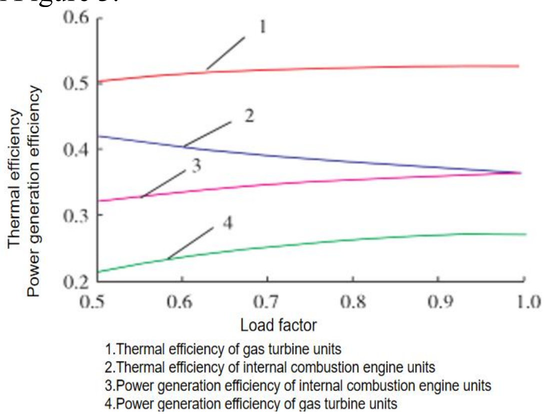

Figure 3. Unit Load Factor and Power Generation (Thermal) Efficiency Correspondence Chart

4. Conclusions

Through the above experiments, students can deepen their understanding of the theoretical knowledge of multi-energy complementary distributed energy system and improve their experimental hands-on ability; they can master the influence of different parameters on solar collector performance and analyze the difference in power generation performance of internal combustion engine under different loads; they can understand the influencing factors of energy utilization of solar-gas complementary distributed energy system.

References

[1] Li L., Zhang Y. J., Xu M. Evolution of energy system form and distributed energy development in China[J]. Distributed Energy, 2017, 2 (1) :1-9.
[2] Tan ZF, Tan QK, Zhao Rui. Review of key technologies for multi-energy complementary systems[J]. Distributed Energy, 2017, 2 (5) : 1-10.
[3] Jin Hongguang, Sui Jun. Transformative energy utilization technologies: distributed energy systems[J]. Distributed Energy, 2016, 1 (1) :1-5.
[4] Hou Junda. Information construction of combined heat and power cooling system[J]. Distributed Energy, 2016, 1 (2) :55-60.
[5] HAJABDOLLAHI H, HAJABDOLLAHIZ, HAJABDOLLAHI F. Soft computing based optimization of cogeneration plant with different load demands[J]. Heat Transfer—AsianResearch,2015.
[6] STANEK W, GAZDA W, KOSTOWSKI W，Thermo-ecological assessment of CCHP (combined cold-heat-and-power) plant supported with renewable energy[J]. Energy, 2015.
[7] GOYAL R, SHARMAD, SONI S L, et al. Performance and emission analysis of CI engine operated microtrigeneration system for power, heating and space cooling[J]. AppliedThermal Engineering,2015,75: 817-825.
[8] FANG F, WEIL, LIU J Z, et al. Complementary configuration and operation of a CCHP-ORC system [J]. Energy,2012,46(1): 211-220.