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Performance and economic of the thermal energy storage systems to enhance the peaking capacity of the gas turbines

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Abstract

There are many gas turbines in Iran favored for coping with the peak electricity demand of the utilities due to their specific properties. However, due to the high ambient temperature in the hot seasons, air mass flow, power output and efficiency of gas turbines decrease considerably. To solve this problem, the inlet air to the gas turbines should be cooled. This paper presents an overview of using the thermal energy storage for combustion turbine inlet air-cooling (TESTIAC) to increase the peaking capacity of it. Several cases of the chilled water and ice storage systems have been studied for the capacity enhancement in Kish power plant. The best case has been selected by economical studies. This study shows that the combustion turbine capacity enhancement will be around 13.6% by using this method. The internal rate of return will be 27.3%. The cost of electricity (COE) is calculated to be 5.36 Cents/kW h which is less than the current price of electricity in Iran on-peak hours.
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Keywords: Kish power plant; Inlet air cooling; Gas turbine; Thermal energy storage; Power augmentation

1. Introduction

There are two methods for reducing the intake air temperature of a gas turbine; one is the direct cooling system in which water is sprayed directly at the inlet of a compressor and the other one is the indirect cooling system in which the inlet air is cooled by the cold water that is produced in a chiller through a heat exchanger installed at the air intake [1]. The direct intake air-cooling system

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Nomenclature

$\dot{m}_{air}$	air flow rate (kg/s)
P	output w.r.t. ISO conditions (%MW)
Q	heat consumption (kJ/kg)
Q_c	cooling load (kW)
T_{amb}	ambient temperature (°C)

is less effective in Kish Island where the humidity levels are high. We have thus focused on the indirect cooling system. Thermal energy storage is one of the indirect systems. In this method the sensible heat capacity of water (water storage) or latent heat of ice (ice storage) is stored in the tank and in hot hours the compressor inlet air is cooled by using the thermal energy storage. The study of the power demand in each month in Kish Island indicates the same pattern. They show two peaks, one at the time interval from 10:00 to 13:00, and the second peak at the time interval from 20:00 to 24:00. The high temperature ambient substantially reduces the power plant output in the hot season when the power sale is most valuable. The designed TESTIAC system is capable of lowering the inlet air temperature of frame-6 combustion turbine (CT) to 7.2 °C at the 45 °C ambient temperature of a hot summer day. The TESTIAC uses inexpensive off-peak (17 h/day) power at night to generate the stored energy in the chilled water for inlet air-cooling during peak demand (7 h/day) periods.

2. Thermal energy storage for turbine inlet air-cooling (TESTIAC) system overview

Two methods can be used for TESTIAC system, chilled water storage and ice storage. The components in these systems are as follows [2]:

(a) mechanical chiller;
(b) ice maker only for ice storage system;
(c) inlet air cooling coil and structure (heat exchanger);
(d) condenser;
(e) pumps.

Chilled water storage systems use the conventional chilling equipment to provide the appropriate chilled water supply temperature to the gas turbine inlet air cooling system. Chilled water storage is most practical in applications with relatively high loads and this system typically uses centrifugal chillers. It generally uses R-134a or R-132 [3]. Also mechanical chillers are used in ice energy storage system to produce cooling energy. The favored tank shape for this system is a flat-bottomed vertical cylinder. A cylindrical tank has a lower surface-to-volume ratio than a rectangular tank of the same volume. A tank with a low surface-to-volume ratio has a lower degree of thermal loss and a lower construction cost per ton-hour of stored cooling.

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