LNG Plant Combined with Power Plant

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Abstract

The LNG plant consumes a lot of power for the natural gas cooling and the liquefaction. In some LNG plant location, a rapid growth of electric power demand is expected due to the modernization of the area and/ or the country. The electric power demand will have a peak in day time and low consumption in night time, while the power demand of the LNG plant is almost constant due to its nature.

Combining the LNG plant with power plant will contribute an improvement of the thermal efficiency of the power plant by keeping higher average load of the power plant, which will lead to a reduction of electrical power generation cost. The sweet fuel gas to the power plant can be extracted from the LNG plant, which will be favorable from view point of clean air of the area.

This paper examined the combination of the plants located in middle east for ;

LNG plant: 6.9 million ton per annum, MTA

Power: 800 mega Watt, MW

The feed natural gas cost was taken as 0.5 \$/MMBtu to 1.0 \$/MMBtu. Simple cycle and combined cycle were studied for the power plant.

This paper confirmed that the combination will contribute the electrical power cost reduction of 0.3-0.4cents/kWh.

Introduction

The LNG plant consumes a lot of power for the natural gas cooling and the liquefaction from ambient temperature to -162 deg.C. In some LNG plant location, a rapid growth of electric power demand is expected due to the modernization of the area and/ or the country. The electric power demand will have a peak in day time and low consumption in night time, while the power demand of the LNG plant is almost constant due to its nature.
Therefore, the concept to combine the LNG plant with power plant will lead the electrical power cost to inexpensive due to the high availability of the power plant.

1. Basis for Study

As the basis of the study following plant configuration was assumed;

LNG Plant: 6.9 MTA, metric ton per annum
The maximum electrical power demand other than LNG plant:
400MW @ 45deg.C ambient temperature.
The average load of power demand other than LNG plant:
70%
Plant Location: Middle East
Design Ambient Temperature for LNG Plant:
29 deg.C

Economic evaluation basis
Feed Gas: Typical middle east gas, sour, contains hydrogen sulfide
Feed Gas Cost: 0.5 -1.0 $/MMBtu, HHV
Fixed Charge Factor: 15%

2. Combination Feature

Following items were considered for the combination of the LNG plant and the power plant.

Elimination of Power Generation of LNG Plant
The power generation unit is eliminated, since the power plant located adjacent to the LNG plant can supply a reliable electrical power, although almost LNG plants are stand alone and the electrical power is generated by gas turbine and/or steam turbines inside of the plant. To keep the availability and reliability of LNG plant, emergency power generation facility should be still kept inside of the plant.

Prime Mover

Most LNG plant is stand alone and the refrigeration compressor is driven by steam turbine or gas turbine. Recent LNG projects have used gas turbine drivers although some expansion projects still apply steam turbine drivers. The thermal efficiency improvement and ease of startup give gas turbine drivers some advantages compared with steam turbine drivers.

Recent LNG plant applied gas turbine driver:

Gas Turbine, Dual Shaft	Arun (ref.-1), NW Shelf (ref.-2), Qatar Gas (ref.-3)
Gas Turbine, Single Shaft	Kenai (ref.-4), MLNG-2 (ref.-5)

The electrical power supply from the power plant adjacent to the LNG plant will replace the gas turbine driver or steam turbine driver to motor.

Fuel Gas to Power Plant

From view point of clean air of the area, the sulfur emission to environment should be minimized and the fuel gas to the power plant can be extracted from pre-treating section of the LNG plant.

Cooling Water Intake

The combined cycle requires a large amount of sea water for the steam cycle of the combined cycle and the requirement will be comparable to that of LNG plant. Therefore the cooling water intake can be combined, although the supply pump and lines should be dedicated to each plant, considering the reliability.

Steam Requirement of LNG Plant

LNG plant usually needs steam as heating media for acid gas removal unit and reboiler duties for fractionation, therefore cogeneration cycle application will contribute the plant efficiency.

However, the steam system trip will have a serious affect for LNG availability of LNG plant, since the steam system trip cause the total liquefaction train shut down including acid gas removal unit and the restart will take longer time. Therefore in this paper, the steam system combination was not considered.

3. Plant Scheme

LNG Plant Scheme

The LNG plant consists of typical three(3) trains with supporting utility facilities and LNG storage and loading facilities suitable for 125,000 m3 LNG tanker loading. The C3-precooled MR process of APCI, Air Products and Chemicals Inc. is assumed as liquefaction process. The typical flow scheme is shown in Fig. 1.

The liquefaction process applies two refrigeration systems, C3 and MR, mixed refrigerant. The propane, C3 is used as precooling of the feed gas and the MR. The C3 refrigerant system applies three(3) refrigeration levels. The C3 vapors from the evaporators are compressed by C3 compressor and cooled and condensed by cooling water. The MR is used for final cooling of the feed gas using spool wound heat exchanger. The vapor from the spool wound heat exchanger is compressed by MR compressors and then cooled by cooling water and C3 refrigerants. The power requirement ratio of C3: MR is 1:2 to3.

Typical configuration was shown in Fig. 2, where one GE Frame 5 is applied for C3 compressor and three(3) GE Frame 5's are applied for MR compressors.

LNG Plant Size: 2.3MTA x 3Train

The refrigeration compressor of each train

C3: 27 MW

MR: 64 MW

The LNG plant will consume

Refrigeration Compressors: 91MW x 3=273MW	
Others:	127
Total	400

The refrigeration compressors are driven by motors instead of mechanical drive gas turbines. Excluding the emergency power, the electrical power will be supplied from the adjacent power plant.

Power Plant Scheme

Two cycles were considered; Simple Cycle

Combined Cycle

Simple Cycle, SC

A schematic diagram for a simple cycle, single shaft gas turbine is shown in Fig. 3. Air enters the axial flow compressor at ambient conditions. Since these conditions vary daily, seasonally or for site, A standard condition is considered for convenience. The standard conditions used by the gas turbine industry are 59F (15C), 14.7 psia (1.013 bar) and 60% relative humidity, which are established by the International Standards Organization (ISO). These conditions are frequently referred to as ISO conditions.

Air entering the compressor is compressed to some higher pressure. No heat is added; however, the temperature of the air rises due to compression, so that the air at the discharge of the compressor is at a higher temperature and pressure.
Upon leaving the compressor, air enters combustion system, where fuel is injected and combustion takes place. The combustion process occurs at essentially constant pressure. The combustion mixture leaves the combustion system and enters the turbine.
In the turbine section of the gas turbine, the energy of the hot gases is converted into work. This conversion actually takes place in two steps. In the nozzle section of the turbine, the hot gases are expanded and a portion of the thermal energy is converted into kinetic energy. In the subsequent bucket section of the turbine, a portion of the kinetic energy is transferred to the rotating buckets and converted to work.
Some of the work developed by the turbine is used to drive the compressor, and the remainder is available for useful work at the output flange of the gas turbine. Typically, more than 50% of the work developed by the turbine sections is used to power the axial flow compressor.
When the feed gas cost is inexpensive, the simple cycle will be economical, since the unit plant cost per kW will be less expensive than the combined cycle, although the thermal efficiency of simple cycle is much less than the combined cycle.(ref.-6)

Typical Designation:
The power plant will be consist of simple cycle of six(6) of GE Frame -7FA equivalent. For example
Designation: PG7231FA
Thermal Efficiency(ISO): 36%
Performance. (ref.6)

Site Temp. deg.C	Net Plant Power, MW	Heat Rate Factor
15	167	1.000
29	153	1.025
45	147	1.053

Combined Cycle, CC
A typical simple-cycle gas turbine will convert 30 to 35% of the fuel input into shaft output.
The combined cycle is generally defined as one or more gas turbines with heat-recovery steam generators in the exhaust, producing steam for a steam turbine generator, heat-to-process, or a combination thereof. Fig. 4 shows a combined cycle in its simplest form. Very high utilization of the fuel input to the gas turbine can be achieved with some of the more complex heat-recovery cycles, involving multiple-pressure boilers, extraction or topping steam turbines, and avoidance of steam flow to a condenser to preserve the latent heat content. Attaining over 80% utilization of the fuel input by a combination of electrical power generation and process heat is

not unusual. Combined cycles producing only electrical power are in the 50% to 60% thermal efficiency range using the more advanced gas turbines. (ref.-6)

Typical Designation:
The power plant will be consist of combined cycle of four(4) of GE Frame -7FA equivalent. For example;
Designation: S107FA
Gas Turbine: PG7221FA
HRSG, Heat Recovery Steam Generator: reheat, unfired type
Thermal Efficiency(ISO): 55%
Performance: (ref.-7)

Site Temp. deg.C	Net Plant Power, MW	Heat Rate Factor
15	253	1.000
29	237	1.001
45	215	1.002

4. Technical Review for the LNG Plant

Compared with stand alone LNG plant, following were reviewed for the combined case.

Synchronous Motor Application

There has never been applied such a big motor driver for the refrigeration compressor of LNG plant. Since there is no induction motor of such size in the market, the driver should be synchronous motor which is basically same construction feature with power generator which has a vast market for such size. There is a few application of synchronous motor for gas compressor for such size by ASEA BROWN BOVERI, ABB.(ref.-8)
For this synchronous motor application, following points were reviewed;

Startup Device:
During the start up of the compressor and the driver synchronous motor, to increase the rotating speed to the synchronous speed against a big torque caused by the compressor, a gradually increased frequency current is introduced from the static frequency converter provided into the synchronous motor. To minimize the start up torque, the compressor is started in reduced suction pressure. After getting the synchronous speed using the variable frequency current from the static frequency converter, the main bus is connected to the synchronous motor, and then the suction pressure increased to normal operating condition, making up the hold up.
The capacity of the static frequency converter was estimated as around 8MW.

Constant Speed for Refrigerant Compressor:
The compressor is driven by synchronous motor, therefore the speed is constant. The compressor control is different from the common variable speed gas turbine driver. The MR compressor flow rate can be controlled by the hold up of the refrigerant.
If the suction temperature of the C3 compressor needs to be constant, it will be controlled by the propane compressor discharge pressure which is controlled by the acting surface area of the propane condenser against the temperature variation of the cooling water or air.

Extra Production
The power plant can supply the demand in case of ambient temperature of 45 deg.C and this will result over 5% extra production compared with stand alone case.

Reliability and Availability Consideration
The reliability of the LNG plant is mainly depend on the gas turbine driver of the power generator for the combined case, while the reliability of the LNG plant is mainly depend on the gas turbine driver in case of stand alone case. The availability of the power plant will be over 90% and the scheduled shut down will be around 5%. The scheduled shut down of the power plant will be incorporated with LNG plant maintenance program, minimizing the LNG plant unavailability.
Therefore, the availability of LNG plant was taken as 90% for this study as well as the stand alone case.

5. Economic Analysis

Based on above, the cases are defined as follows.

Definition of Case
The stand alone case was also evaluated for the comparison with the combination of LNG plant and the power plant.
The gas turbine cycle was considered for the power plant considering the recent high availability and the high thermal efficiency. Two cycle i.e. simple cycle, SC and combined cycle, CC were considered .

Study Cases:

Combination;	Stand Alone	Stand Alone	Combined	Combined
Gas Turbine;	SC	CC	SC	CC

The economic evaluation was made for the feed gas cost of 0.5$/MMBtu and 1.0 $/MMBtu. Plant costs were estimated as follows based on appropriate basis.

LNG Plant Cost:	Stand Alone:	2,000 million $
	Combined Case:	1,900million $
Power Plant Cost:	Combined Cycle:	600$/kW
	Simple Cycle:	450 $/kW

Case Study Results

The LNG cost is shown in Table-1. The table shows the combined case will have no cost difference against the stand alone case, although the extra production will make profit if the LNG market can absorb it.

The electrical power cost is shown in Table 2 and Fig. 5. The table shows the combined case will have 0.3-0.4 cents/kWh cost merit against the stand alone case. The combined cycle, CC will not have a cost merit for simple cycle for this feed gas cost range, although CC will have an advantage for the feed gas cost above 1.0 $/MMBtu.

Table-1 LNG Cost, $/MMBtu

	Stand Alone	Stand Alone	Combine	Combine
GT Cycle	SC	CC	SC	CC
Feed Gas 0.50 $/MMBtu	1.68	1.68	1.68	1.70
Feed Gas 1.00 $/MMBtu	2.26	2.26	2.25	2.25

Table-2 Electrical Power Cost, cent/kWh

	Stand Alone	Stand Alone	Combine	Combine
GT Cycle	SC	CC	SC	CC
Feed Gas 0.50 $/MMBtu	2.1	2.4	1.8	2.1
Feed Gas 1.00 $/MMBtu	2.7	2.8	2.4	2.4

6. Conclusion

The concept to combine LNG plant with power plant was confirmed to have economical advantage compared with the stand alone case from view point of LNG cost and electrical power cost for the range of the feed gas cost 0.5-1.0 $/MMBtu.

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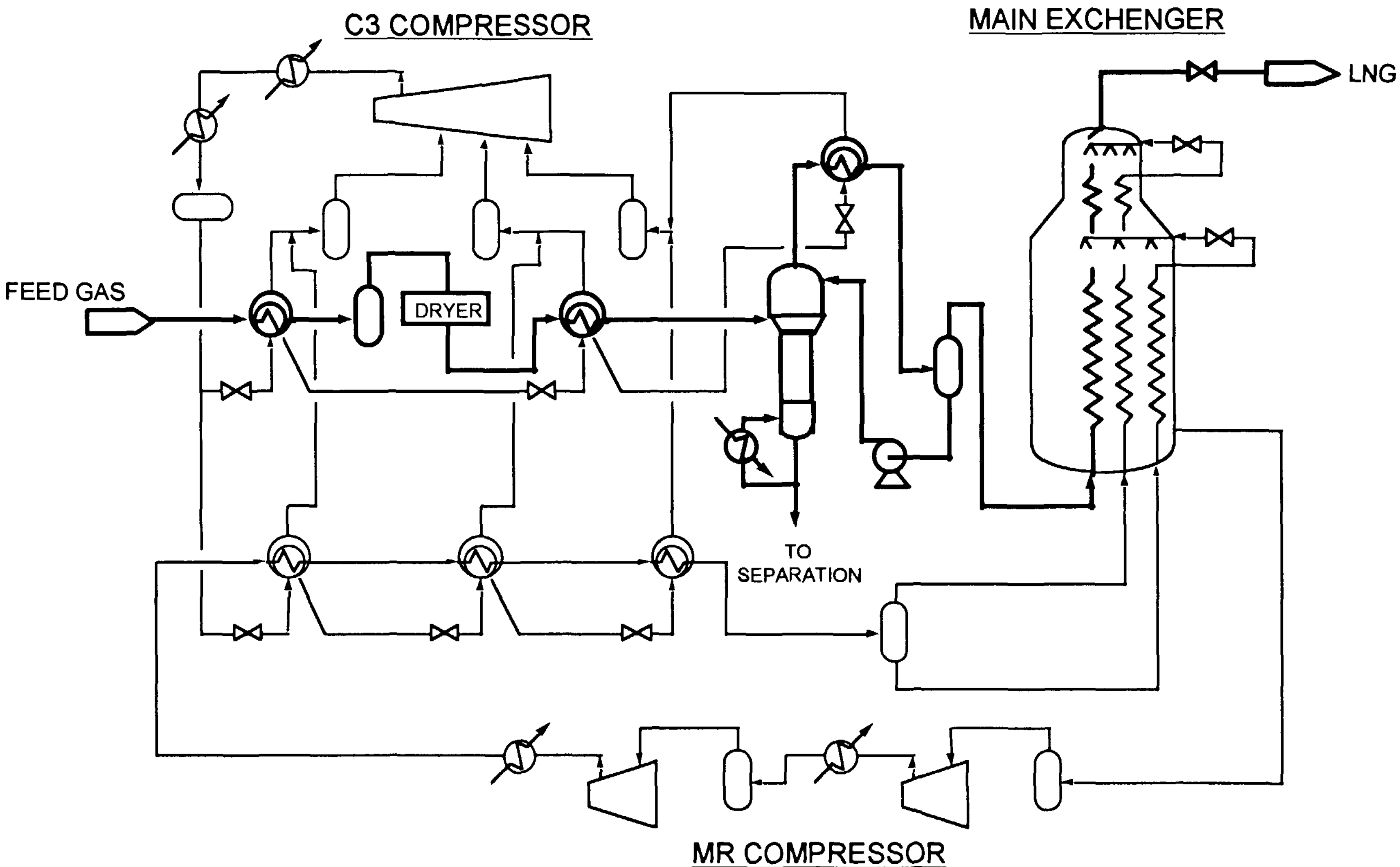

Fig. 1 C3-MR (APCI) Process Scheme

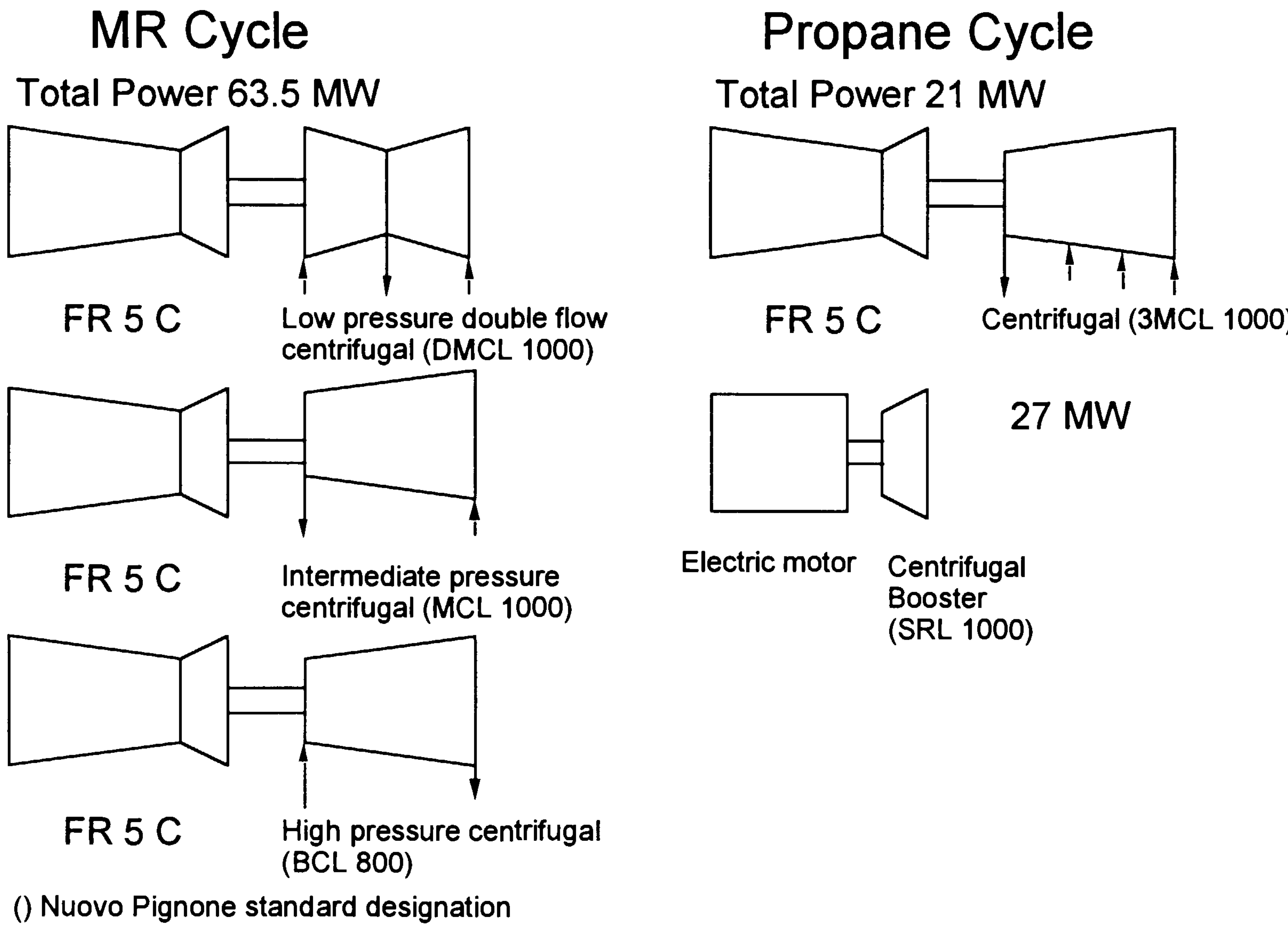

Fig. 2 QATARGAS 2.3 MTA Refrigeration Compressor Scheme

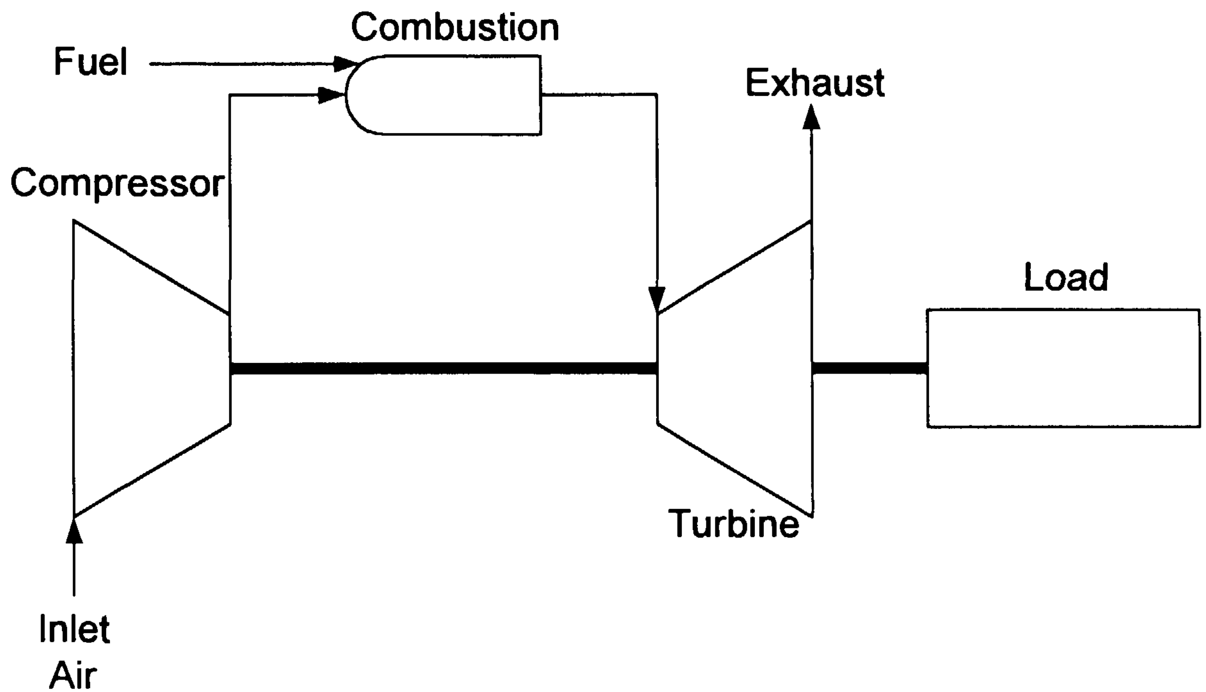

Fig. 3 Simple-cycle, single-shaft gas turbine

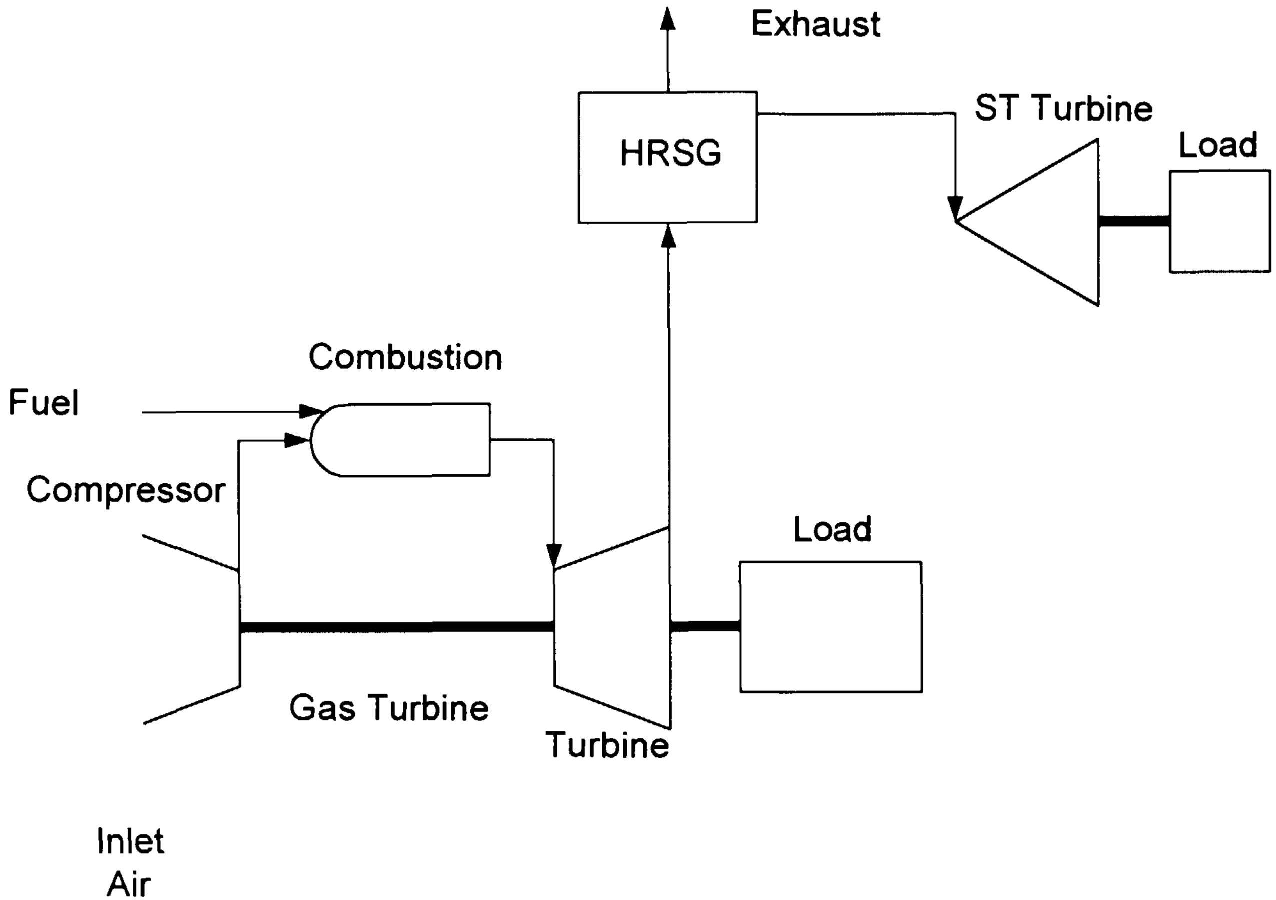

Fig. 4 Combined cycle

Fig. 5 Electrical Power Cost vs. Feed Gas Cost