TECHNIQUES OF CCHP AS A RIGHT WAY TO APPLY THE 2ND LAW OF THERMODYNAMIC: CASE STUDY (PART ONE)

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Abstract

Paper illustrates the design of an "Efficient Energy System" (EES) to supply energy to a new hospital of Catania (CH). It is shown the way to build EES through CCHP techniques and the analysis of energy request of EES during whole period of year. Paper shows also as EES , and connected CCHP techniques , achieves on the basis of 2nd Law of Thermodynamic significant economical decreasing of operational costs of CH and remarkable environmental benefits.

Keywords: Energy System, Design, CCHP, Hospital

Introduction

The area of pertinence of CH covers about 230,500 m^2 of which 28,500 m^2 with a built cubage of 405,000 m^3 (Fig.1 and Fig.2). Environmental balance was evaluated comparing polluting air emissions expected from the EES with the pollution of an energy supplying trough traditional system. A reduction of impact on environmental component "atmosphere" was arose by the designed Thermodynamic Architecture and Plants. The EEC takes to a significant reduction of pollution influencing "atmosphere".

The main data about HC are:

Plan features	:	applied research and constructive performance
Customer company	:	San Marco Hospital – Catania (Italy)
Planning	:	Thermodynamic Architecture and Plants planned by Authors
Funding	:	Regional Department of Health of Sicily (Italy)
Value of fulfillment	:	Cost of EES plants more than € 18,000,000
Achieving purposes by	:	production of 5,25 MW$_e$ (electrical power) and

EES		simultaneously production of 11,0 MW_t (heat energy) to feed HVAC plant and to supply energy for “hot sanitary water” and other utilities
Market	:	since the beginning of planning Designers considered a surplus of electricity production , in relation with requires of CH, to market to National Electrical Network for about ~ 150,000 €/year
Currently status	:	forecasted end of work the next December 2015.

Fig. 1 – CH perspective Nord

Fig. 2 – CH Perspective Est

For room reason, since the extended size of subject, the treatise of topics will show in three part of which the first in present paper.

- part one: thermodynamic of EES and short description of loop of plants
- part two: quantification of environmental benefits
- part three: quantification of economic benefits.

Efficient Energy System (EES)

A gas turbine (Typhoon of Siemens) powered by methane and coupled with an alternator and one Heat Recovery Steam Generator (HRSG), supplies electric power of 5,25 MW_e, more than amount needed by CH during operation. Following the basis of 2nd Law of Thermodynamics, thermal energy abundantly contained in exhaust gasses of turbine, continuously at intervals of temperature well-defined and with decreasing values of temperature for each interval, powers a sequence of CH operational functions. By appropriate heat exchanges with water, previously thermal energy is exploited to produce low-pressure steam to power cooling absorption cycle, to produce hot sanitary water, to produce hot water for various utilities, to feed HVAC plants and so on. Fig. 4 shows the final energy architecture of EES.

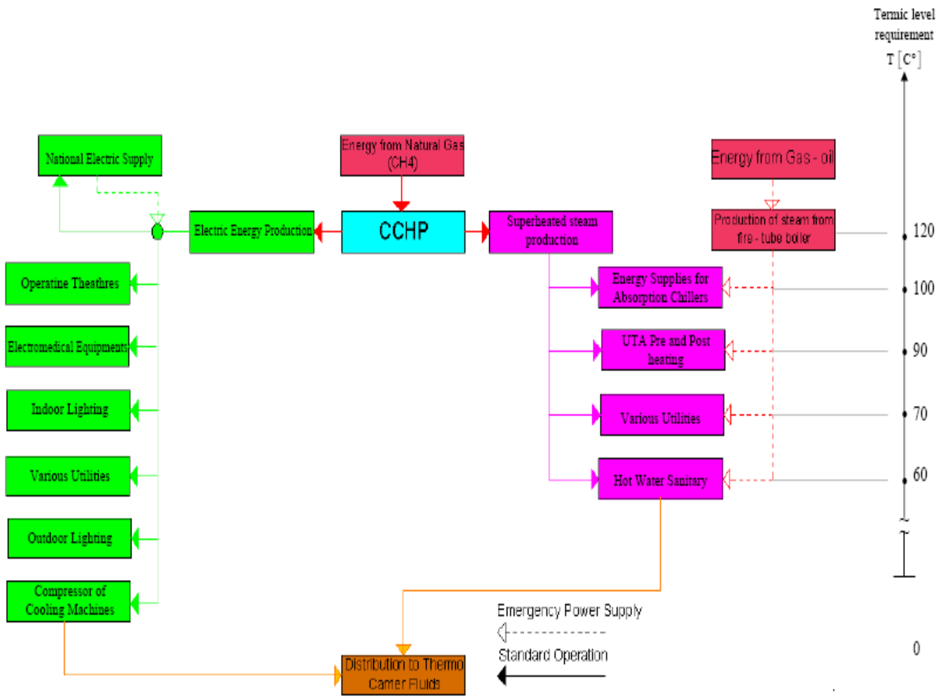

Fig. 4 – Architecture of EES.

Energy required of CH

Opting for a slights dependence from National Electrical Network, cogeneration group will operated 24 hours at full-load in June, July and August, at 70% of full-load in January, February, March, April, May, June, September and December and at 50% in October and November. Tab. 1 shows the equivalent hours of operation of cogenerator.

Based on previous operational times people forecast:

– Steam request for HVAC: about 23,75 tons/h in Summer time (that in Sicily is from May to August) and about 14,60 tons/h in Winter time (from November to February).

The request is less and variable in Spring time and Autumn time in function of real local conditions of weather climate.

– Tab.2 shows electrical power request for indoor and out-door lighting and for various utilities (Electro-medical equipments etc. etc.)

– Tab.3 shows thermal power request for hot sanitary water, HVAC etc. etc.

Months	**Days**	**Operating time (h)**	**% of full-load operation ε**	**Equivalent time of full-load (h)**	**Total equivalent (h)**
January	31	24	70	16,80	520,8
February	28	24	70	16,80	470,4
March	31	24	70	16,80	520,8
April	30	24	70	16,80	504,0
May	31	24	70	16,80	520,8
June	30	24	100	24,0	504,0
July	31	24	100	24,0	520,8
August	31	24	100	24,0	520,8
September	30	24	70	16,80	504,0
October	31	24	50	12,00	520,8
November	30	24	50	12,00	504,0
December	31	24	50	12,00	520,8
Total yearly	**365**	**8.760**			**6,133.0**

Tab. 1 – Equivalent hours of operation of cogeneration group

Unit of air treatment	815 Kw_e
Outdoor lighting	60 Kw_e
Indoor lighting	350 Kw_e
Electrical medical equipments	1,200 Kw_e
Centrifugal compressors (n. 14)	3,219 Kw_e
Medical operation rooms (n. 14)	560 Kw_e
Various utilities	936 Kw_e
Total amount	**7.140 Kw_e**

Tab. 2 - Forecast request of CH electrical power

Summer time	[Kw_t]	Winter time	[Kw_t]
Hot sanitary water	1,425	Hot sanitary water	1,425
Cooling batteries for U.T.A.	538	Post heating (HVAC)	5,650
Absorption cooling machines	12,887	Hot separated circuits	1,415
Various utilities	1,650	Various utilities	1,650
Total amount	**16,500**		**10,140**

Tab. 3 – - Forecast request of CH thermal power

Main machines and equipments

- CH cogeneration group (Typhoon – Siemens) including gas-turbine, electrical power unit and HRSG:

- Forecast units	:	n.1
- Output of electrical power	:	>5,100Kw_e
- Steam out-put	:	12,750 Kg/h at 10 bar
- operational parameters for best efficiency	:	> 96%
- height on sea level	:	50 ÷ 90 m
- temperature	:	15 °C
- atmosphere pressure	:	1,007 bar
- features of exhaust gas	:	T = 535 ÷ 550°C M' = 20,4 Kg/s
- combustive air flow rate	:	M' = 80 ÷ 82 Nm^3/h

- Fire-tube boiler:

- units n. 3
- nominal power: n° 3 x 2,780 Kw_t = 8,340 Kw_t
- steam production: n° 3 x 5000 Kg/h = 15,000 Kg/h

- Cooling machines at compression cycle:

- units n. 2
- "cold" production: n° 2 x 4,079Kw_f = 8,158 Kw_f

- Cooling machines at absorption cycle:

- forecast units n. 2
- "cold" production: n° 2 x 4,037 Kw_f = 8,174 Kw_f

Types of management

On the basis of energy requests, there are two types of management:

I - Full-load management, in absence of anomalies or unexpected occurrences during operations

- Peak of electrical request: 7,14 Mw_e of which 5,125 Mw_e by electrical power unit of cogeneration group and 2,02 Mw_e by local electrical network.

- Peak of thermo-refrigerating request: 16,50 Mw_f of which 2 x 4,15 Mw_f by absorption cycle machines and 2 x 4,15 Mw_f by compression cycle machines.

Management in case of unexpected emergencies.

There are two main emergences:

- First occurrence: in case of blackout of local electrical network.

The smallest evaluated energy request of CH in emergency are:

- electrical load: the 60% of full load, that is 4,28 Mw_e. Cogeneration group (5,125 Mw_e) supplies this amount

- thermal load: the 50% of full load, that is 8,33 Mw_t. Cogeneration group supplies this amount too (8.88 Mw_t)

- Second occurrence: in case of blackout of cogeneration group.

The smallest evaluated energy request of CH in emergency are:

- electrical load: the peak of 7,14 Mw_e fully supplied by local electrical network

- thermal load: the peak of 8,33 Mw_t supplied by n. 3 fire-tube boilers.

Tab. 4 shows the synoptic frame of energy requests and relative supplies in various operating conditions.

Kind of operation	Electrical request [Mw_e]	Electrical supply [Mw_e]	Thermo-refrigerating request [Mw_t]	Thermo-refrigerating supply [Mw_t]
Full load operation	7.14	5.125	16.5	8.25
		2.02		8.25
Various intermediate loads operation	Automatic variation of loads controlled by computer programs			
First emergency op.	4.28	5.125	8.33	8.85
Second emergency op.	4.28	7.14	8.33	8.33

Cogeneration group ctrical network M ine at absorption cycle
Machine at compression cycle F ube boiler

Kind of operation	Steam request [Kg/h]	Steam supply [Kg/h]
Full load operation	14,600	12,745
		3,000
	23,750	12,745
		12,000
First emergency op.	14,596	12,750
		3,000
	14,596	12,750
		3,000
Second emergency op.	14,596	15,000
	14,596	15,000

Environmental heating operation vironmental cooling operation
Cogeneration group -tube boiler

Tab. 4 – Synoptic frame of supplies.

Energy balances

Based on real data coming from others hospitals about similar to CH as regard medical functions and number of beds (~ n. 700), it is extrapolated “equivalent hours of operations” as previously shown in Tab. 1. By data of Tab. 1, Tab. 5 shows the forecast amount of electrical energy to market to national electrical network

Months	Forecast request [KWh_e]	Forecast production by cogenerator [KWh_e]	Forecast marketable energy [KWh_e]
January	1,560,000	2,513,232	953,232
February	1,495,000	2,270,016	775,016
March	1,430,000	1,621,536	191,536
April	1,300,000	2,432,160	1,132,160
May	1,430,000	2,513,232	1,083,232
June	2,340,000	2,432,160	92,160
July	2,860,000	3,589,800	729,800
August	2,470,000	3,589,800	1,119,800
September	1,950,000	2,432,160	482,160
October	1,495,000	1,795,272	300,272
November	1,430,000	1,795,272	365,272
December	1,495,000	1,795,272	300,272
Total yearly	**21,255,000**	**28,779,912**	**7,524,912**

Tab. 5 – Marketable electrical energy

Conclusion

- It is possible to get a high efficiency of loop of plants supplying energy for any kind of buildings or industrial processes if the thermodynamics design get a rational exploitation of energy based on Second Law of Thermodynamic.
- There is not general routine to design EES as there are many parameters at the basis of design: kind of activities carried out in construction, weather-climate of location, materials forecasted in architectural design, electrical and thermal power required etc., etc.

All that previously parameters reported implies the needing to design an aimed EES for each kind of buildings.

- Thermodynamic design changes always for each changing of singular category of constructions.
- The right design of EES takes to economic benefits since decreases operational costs.
- EES takes to environmental benefits since decreases amount of polluting matters yearly leaded into atmosphere.

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Symbolism:

CCHP: Combined Cooling Heating and Power
EES: Efficient Energy System
CH: Hospital of Catania
HVAC: Heating Ventilation and Air Conditioning
HRSG: Heat Recovery Steam Generator
e (subscript): electrical
t (subscript): thermal
f (subscript): refrigerating
UTA: Air Treatment Unit
TOE: Tons of Oil Equivalent