Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 45 (2014) 405 – 414

Energy Procedia

68th Conference of the Italian Thermal Machines Engineering Association, ATI2013

Implementation of a simulating code for heating and cooling networks for residential, commercial and tertiary buildings

Giorgio Cucca[a], Andrea Porcu[a] and Chiara Palomba[a]*, Biagio Di Pietra[b], Giovanni Puglisi[b], Danilo Sbordone[c]

[a] Dipartimento di Ingegneria Meccanica Chimica e dei Materiali, via Marengo 2, Cagliari 09128, Italy
[b] ENEA, via Anguillarese 301, S. Galeria Roma 00123, Italy
[c] Università La Sapienza,via delle sette sale 12/b , Roma 00184,, Italy

Abstract

In the present energy scenario in which efficiency and sustainability will take the primary role in the decision making process it becomes more and more important to dispose of reliable simulating codes which allow to highlight the pros and cons of a given energy installation. New and old (forgotten) technologies are nowadays challenging the traditional technologies in different sectors of energy transformation from power generation down to heating and air conditioning. In the present situation of fuel cost oscillations and with the perspective of long-term scarcity of fuels, new, less energy demanding systems must be employed to maintain the actual comfort level. The present work aims at creating a reliable tool for correct evaluation of energy performance of heating and cooling networks.
A code has been implemented in Simulink environment to simulate the network behaviour in summer and winter weather condition and to evaluate the primary energy indexes for comparison with the traditional configuration of a distributed heating and cooling plants common in residential, commercial and tertiary sectors. The code has been validated and the results will show the energy, economic and environment feasibility and convenience of one solution with respect to another for different climatic regions in Italy.

Selection and peer-review under responsibility of ATI NAZIONALE

Heating and cooling networks; trigeneration; cogeneration: energy efficiency.

* Corresponding author. Tel.: +39-0706755720; fax: +39-0706755717.
E-mail address: chiara.palomba@dimcm.unic.it

Selection and peer-review under responsibility of ATI NAZIONALE
doi:10.1016/j.egypro.2014.01.044

1. Introduction

Modern societies are heavily dependent on energy and must, therefore, be confronted with every aspect related to its use. While the main concern in the past was merely that of energy cost, the progressive impoverishment of the available energy sources and the growing environmental issues due to energy use related emissions raises the new problem of sustainable use of energy. This term may be understood in different ways but it is explicatory in the sense that comprehends both the idea of durability in time and compatibility with the environment.

Nomenclature

COP	Coefficient Of Performance
CZ	Climatic zone
EUF	Energy Utilization Factor
MCI	Internal Combustion Engine
MFA	Absorption Chiller
TCO_2ER	Trigeneration CO_2 emission reduction
TPES	Trigeneration Primary Energy Saving

Symbols

μ	Emission factor (g/kWh_e)
F	Fuel thermal content (kWh_t)
H	Trasmittance (W/ m^2K)
Q	Heat (kWh_t)
R	Cooling (refrigeration) (kWh_c)
V	Volume (m^3)
W	Electricity (kWh_e)
ρ	Density (kg/ m^3)

Subscripts

ACC	Storage
ASS	Absorpition Chiller
CH	Elettric Chiller
E	Electricity
PM	Prime mover
Q	Heat
SP	Separate Production
t	Thermal

The European Union program Europe 2020 [1] was launched to promote a sustainable growth and is based on the following key points to be achieved by the year 2020:

- attain a green house gas emission reduction of 20% with respect to the levels of year 1999. The EU is willing to move up to 30% reduction in presence of a global agreement in which the other developed countries commit to the same values and the developing countries commit to lower values compatible with their economic capacity.
- Produce 20% of the final consumption by renewable energy sources
- Increase energy efficiency of 20% .

The EU directive 2012/27 UE, identifies high efficiency cogeneration (CAR), heating and cooling networks as important means to achieve the energy efficiency goal. In this sense it promotes the development of distributed generation and small networks. However, it also underlines the need to improve the modelling tools in order to better simulate the equipment behaviour and find high efficiency technical solutions. The present work, which aims at the implementation of a simulating tool in Matlab-Simulink environment for heating and cooling networks, is framed in this perspective. The simulations should allow, not only to calculate the transient conditions but also to ascertain the efficiency parameters in order to evaluate the real advantages of the network configuration with respect to the separated production. Moreover, it should be able to quantify the difference in performance of alternative technical solutions. This work is part of the wider research program of ENEA "Ricerca di Sistema Elettrico" (RSE), whose aim is to reduce electrical energy cost for the final user, increase the quality and reliability of the electric supply service, reduce the electrical system environmental and health impact and rationalise the use of resources to provide the Country with a sustainable grow. The present code was developed on the base of a pre-existing code which simulates heating networks for residential use only [2]. The challenge was that of adding the cooling function and to include commercial and office building. There is a growing interest and use of this kind of networks in the world: in Italy between 2009 and 2010 there has been an increase of 16% of the thermal energy conveyed by networks [3]. One example of a large investment in the field is represented by the program "Sustainable Sydney 2030 - The vision" [4]. The town objective is that of reducing green house gas emissions by 70% with respect to the values of the year 2006, and this by the year 2030. This is to be achieved through the extensive use of trigeneration plants localised in the city to supply the user through an energy distribution network. Similar programs are currently under evaluation in other parts of the world [5] demonstrating the strong interest for a simulating tool capable of analysing the energy performance of a heating and cooling network.

2. Code description

The code has been developed to satisfy certain specifications in the description of the energy dispatching. It should allow to simulate the dynamic behaviour of the whole system of energy distribution following the time transients. The software is subdivided into five macro-blocks each of one provides and exchanges data with the others. In Fig. 1, the five blocks and their interconnections are represented.

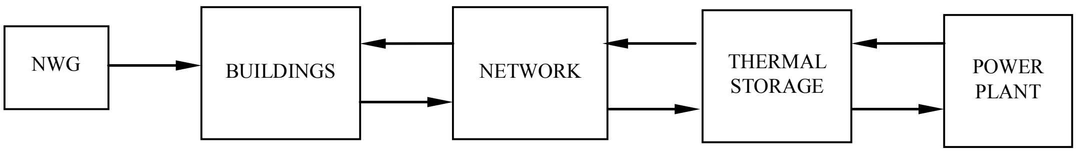

Fig. 1) Block scheme of the code

Starting from the left, the first block represents the Neural Weather Generator, NWG. This block, which had been previously developed by ENEA, provides the code with the necessary ambient data to perform unsteady simulations, such as air temperature and sun radiation. In fact the buildings' thermal load and the windows' thermal gain change continuously in time due to outside ambient daily and seasonal variations and differently according to the specific wall or window orientation. Further information about this part of the code may be easily found in report [6] and publication [7]. The second block from the left describes the buildings. The original residential building code, better described in [8], has been the base for the implementation of different types of buildings. In the present code, three different buildings have been simulated and the main geometrical and structural data are presented in tables 1, a, b, c. Each building is destined to a different use: residential, commercial and tertiary (office). Therefore, different hourly profiles had to be provided to the code as far as lighting, occupation and air exchange are concerned. Table 2, and Fig. 2 and 3 represent the weekly time schedules used in the simulation.

The third block, represents the network, and it was the one requiring a deep modification to add the cooling function. The simulated network has a radial configuration with a central topline from which the secondary lines depart to reach the different users, as shown in Fig. 4. This is a single line network allowing, therefore, only the seasonal trigeneration as it is typical for cases in which the cooling energy is mainly required in summer. In table 3, the network dimensions are shown in terms of length of the different network lines. The fourth block consists of a thermal storage and it has been modified with respect to the original code [2] by including in it the network thermal inertia, while the losses are calculated separately. The code can calculate the temperature value in each node of the net, calculated as mixing temperature of the different streams reaching each node. Moreover, it calculates the thermal losses towards the ground. In order to reduce the amount of input data and calculation time and demand, considering that a year-long simulation is performed with a time step of 900 s, some simplification have been introduced still granting a sufficient precision in the calculated output.

Table 1.a. Commercial building

Property		
Hight	m	9
Length	m	25
Width	m	20
Total heated area	m^2	1000
Volume	m^3	4500
Shape factor		0,29
Floors	n°	2
Thermal Transmittance Outer Wall	W/ m^2K	0,4322
Thermal Transmittance Window	W/ m^2K	2,529
Floor Thermal Transmittance	W/ m^2K	1,455
Ground Floor Thermal Transmittance	W/ m^2K	0,487
Ceiling Thermal Transmittance	W/ m^2K	0,5457

Table 1.b. Tertiary building

Property		
Hight	m	10
Length	m	10
Width	m	20
Total heated area	m^2	600
Volume	m^3	2000
Shape factor		0,5
Floors	n°	3
Thermal Transmittance Outer Wall	W/ m^2K	0,310
Thermal Transmittance Window	W/ m^2K	2,616
Floor Thermal Transmittance	W/ m^2K	0,362
Ground Floor Thermal Transmittance	W/ m^2K	0,357
Ceiling Thermal Transmittance	W/ m^2K	0,326

Table 1.c. Residential building

Property		
Hight	m	10
Length	m	10
Width	m	10
Total heated area	m^2	300
Volume	m^3	1000
Shape factor		0,6
Floors	n°	3
Thermal Transmittance Outer Wall	W/ m^2K	0,310
Thermal Transmittance Window	W/ m^2K	2,616
Floor Thermal Transmittance	W/ m^2K	0,362
Ground Floor Thermal Transmittance	W/ m^2K	0,357
Ceiling Thermal Transmittance	W/ m^2K	0,326

Table.2 Weekly schedule

Building	Schedule	
	Mon-Fri	Sat-Sun
Commercial	9-20	9-20
Tertiary	7-18	off
Residential	18-24	18-24

Table 3. Network dimensions

Sector	[m]
L0	4
L1	4
L2	375
L3	125
L4	100

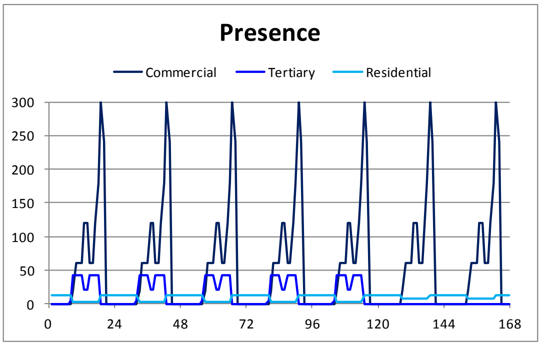

Fig. 2 Presence weekly schedule

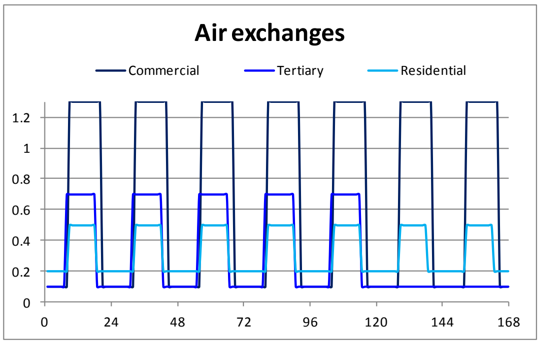

Fig. 3 Air exchanges weekly schedule

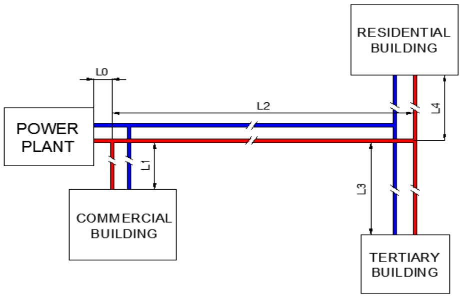

Fig. 4. Network outline

The simplifications introduced are briefly explained as follows. The temperature of the working fluid along the whole network, and more specifically in the derivation nodes at the entrance of each building, is calculated according to equation (1), more fully described in [9]. The required data are the fluid temperature at the network inlet (T_0), which corresponds to the exit temperature of the thermal storage downstream of the prime mover in the outgoing line and to the fluid temperature at the heat exchanger exit in the coming back line, and the ground temperature (T_a).

$$T(x,t) = T_a + \left(T_{0(t)} - T_a\right) \cdot e^{-\frac{2\cdot\pi\cdot r\cdot H}{G\cdot\gamma}\cdot x} \quad (1)$$

In which G is the mass flow of the working fluid, r and H are respectively the mean tube radio and the tube transmittance, while γ is the working fluid specific heat (water in the present case), and x is the tube length. This simplified formula is based upon the following assumptions:

- Steady flow;
- Uniform value for temperature T_a;
- One dimensional flow: temperature may vary only along the tube length and nota long the radius;
- Fluid properties are constant.

This formula is sufficiently precise only in a limited range of mass flow, $G = 70 \div 90\ [kg/sec]$, not covering the small mass flow values of the present network. Therefore a correction factor has been calculated and applied considering that in reference [10], it is stated that for small dimension networks operating with water at 90°C temperature, the temperature gradient along the lines is $0{,}1[°C/km]$. The correction coefficient has been evaluated on the base of the mean mass flow in each tube section.

As the calculation moves along the line, the temperature $T_{0(t)}$ becomes the known temperature of the preceding node in the outgoing line of the network, while in the coming back line, since at each node different streams from the pipe lines arrive and mix, the node temperature has been calculated according to mixing equation 2 in which the specific heat of the working fluid is set constant due to the small temperature difference among the streams:

$$T_{node} = \frac{T_1 \cdot m_1 + T_2 \cdot m_2}{m_1 + m_2} = [°C] \quad (2)$$

With the simplifications introduced, the algorithm allows the calculation of the working fluid temperature in each point along the network lines. The inertia of the network has been calculated as the one associated to the fluid contained in it, and this inertia will be added to the one of the thermal storage close to the prime mover. Therefore, the time evolution of the thermal storage temperature has been calculated according to equation 3.

$$\frac{dT}{dt} = \frac{Q_{load} - Q_{aux} - \left(H_{acc} \cdot Sup_{acc} \cdot (T_{acc} - T_{terreno})\right)}{c_p \cdot \rho \cdot (V_{acc} + V_{rete})} \quad (3)$$

In which, Q_{load} and Q_{aux} respectively represent the energy given to the buildings and the energy given to the storage, either by the prime mover or by the absorption chiller. The symbols V_{rete} e V_{acc} respectively represent the fluid volume contained in the network and in the storage, H_{acc} represents the storage transmittance and Sup_{acc} is the heat exchange area of the storage. Finally, T_{acc} and $T_{terreno}$ respectively represent the storage temperature and the ground temperature (the thermal storage is also underground).

The original code developed for heating operation only, used the thermal storage to simulate the thermal inertia of the network, while as the power required by the buildings was higher in the present network, the storage is a physical one whose dimension has been chosen as the minimum dimension necessary to guarantee a stable functioning of the network during transients. The thermal storage has a volume of 10 m^3 for all simulations. Thermal energy losses associated to the storage have been calculated according to equation 4 in which FF_{acc} is the storage shape factor.

$$Q_{loss} = FF_{acc} \cdot V_{acc} \cdot H_{acc} \cdot (T_{acc} - T_{terra}) \quad (4)$$

Finally, the fifth block, represents the power station. An internal combustion engine has been chosen and implemented. This choice derives from the consideration that the network requires heat at relatively low temperature and that the internal combustion engine maintains high values of the electric efficiency at part load with respect to the alternative solution constituted by micro gas turbine.

3. Description of simulating conditions

In order to verify the correct functioning of the simulating code, its abilities have been tested placing the network in three different cities corresponding to different Climatic Zones (CZ): Milan (CZ E), Rome (CZ D) and Palermo (CZ B). The main difference can be summoned to the relative weight between heating and cooling, and the different operating times which depend on weather conditions. The system firing dates for the three climatic zones are defined by the law and are stored in a data file, while for each Climatic Zone the network inactivity time lap has been evaluated to avoid Energy waste in spring and fall.

The network should provide heating and cooling to the final users with a cogeneration scheme in winter and a trigeneration scheme in summer. While for the winter operation the configuration is set by the prime mover plus the thermal storage, different choices are possible for the trigeneration. In the literature, as an example in [3, 4], it was seen that two possible configurations are mainly used: either with a centralised absorption chiller or with absorption chillers distributed in the different buildings. Therefore, three different configurations have been simulated.

- Scenario 0, in which the heat, cooling and the electricity are independently provided without the network: the commercial building has a heat pump for winter and summer conditioning, while the residential and tertiary buildings have a boiler for winter and a heat pump for summer. This is the normal condition in towns and it will be used as a reference to compare the energy and environmental benefit of the network.
- Scenario1 in which the absorption chiller is located by the prime mover.
- Scenario 2 in which each building has its own absorption chiller. The equipment used in each scenario is described in tables 4, 5 and 6 in terms of installed power. The power values have been adapted to the specific needs of the final users.

4. Network performance indexes

When dealing with such micro-networks as the one simulated on the program implementation phase, it is difficult to find experimental data for validation, although this is not a problem uncommon even for larger dimension networks, since the network's managing companies very rarely share this kind of information. Therefore, a mean to evaluate the program performance must be found. It was, then, though of calculating the yearly performance indexes and compare the results with the typical values for similar cases. The purpose of implementing a heating and cooling network is that of achieving money and or energy savings. Therefore, the performance of the network must be compared with the one of other equipment capable of supplying the same service to the final user. Three different performance indexes have been chosen and will be briefly described in this paragraph.

Table 4. Equipment power. *Scenario 0*

	Commercial [kW]	Tertiary [kW]	Residential [kW]
Milan	100	60/45	25/20
Rome	100	50/45	20/20
Palemo	110	35/55	12/20

Table 5. Equipment power. *Scenario 1*

	MCI [kW]	MFA [kW]
Milan	90	70
Rome	90	80
Palemo	110	95

Table 6. Equipment power *scenario 2*

	MCI [kW]	Commercial MFA [kW]	Tertitiary MFA [kW]	Residential MFA [kW]
Milan	90	55	25	14
Rome	115	65	30	20
Palemo	130	70	45	20

The first index is the Energy Utilisation factor EUF [11], which for a prime mover represents the ratio of the useful energy to the fuel energy input.

$$\mathrm{EUF} = \frac{\mathrm{E_Q} + \mathrm{E_E}}{\mathrm{F_{PM}}} \tag{5}$$

This index is strongly influenced by the prime mover chosen and by the enthalpy level of the recuperated heat: while for micro gas turbines it makes no difference, in the case of combustion engines part of the heat can only be exchanged at relatively low temperature.

During summer, the system operates in trigeneration configuration. Therefore, specific indexes have been calculated to evaluate both the energy and the environmental performance of the seasonal trigeneration operative mode: the Trigeneration Primary Energy Saving TPES and the Trigeneration CO_2 Emission Reduction TCO_2ER.

The TPES formula used has been modified according to [11, 12]. In fact, the "Zero Scenario" with which the network performance must be compared, uses both boilers and heat pumps for heat production.

$$TPES = \frac{F^{SP} - F_Z}{F^{SP}} = 1 - \frac{F_Z}{\frac{W_Z}{\eta_e^{SP}} + \frac{Q_Z}{\eta_t^{SP}} + \frac{Q_{Zc}}{\eta_e^{SP} \cdot COP_H^{SP}} + \frac{R_Z}{\eta_e^{SP} \cdot COP_C^{SP}}} \tag{6}$$

In the preceding formula, the chillers' performance is included for both heating (H) and cooling (C) modes. The performance has been evaluated through the Coefficient of Performance COP. This index compares the energy input to the useful cooling energy. Since two different types of heat pumps, electric and absorption chiller, are involved in the code simulation a differentiation must be made in the evaluation of the COP coefficient with respect to the energy input as show in equations 7 and 8.

$$COP_{CH} = \frac{R_C}{W_{CH}} \tag{7}$$

$$COP_{ASS} = \frac{R_C}{E_Q} \tag{8}$$

In the simulation three scenarios have been implemented. The Zero Scenario only uses Heat Pumps and the COP values for winter and summer operation are shown in Table 7. The Scenario 1 and 2, in which the network is operating, respectively employ a single centralised absorption chiller and three absorption chillers distributed in the buildings. The COP values are shown in Table 8.

Table 7. COP Heat Pump *scenario 0*

	Winter	Summer
Milan	2,457	3,031
Rome	-	3,01
Palemo	-	2,939

Table 8. COP MFA

	Scenario 1	Scenario 2 Commercial	Scenario 2 Tertiary	Scenario 2 Residential
Milan	0.7792	0.7258	0.7536	0.7325
Rome	0.7388	0.686	0.715	0.6899
Palemo	0.7133	0.6549	0.6786	0.6619

As far as the electricity and heat production is concerned, three different possibilities have been taken into consideration for the Zero Scenario performance parameters.

- **Case 1:** $\eta_t^{SP} = 0{,}95$ e $\eta_e^{SP} = 0{,}58$ - This case, which could be called Best Available Technology (BAT), assumes performance values of best boilers and best combined cycle production plant.
- **Case 2:** $\eta_t^{SP} = 0{,}90$ e $\eta_e^{SP} = 0{,}525^*$ - In this case, the performance values are those proposed in the D.M. 4 August 2011, the electric efficiency is calculated taking into account the climatic zone and the grid voltage connection (<0,4kV).
- **Case 3:** $\eta_t^{SP} = 0{,}925$ e $\eta_e^{SP} = 0{,}46$ - The thermal efficiency is slightly lower than in Case 1, while the electric efficiency is referred to the average value for the national production.

The same modifications used for the TPES coefficient are applied to the TCO_2ER coefficient [11,12].

$$\mathrm{TCO_2ER} = 1 - \frac{\left(\mu_{CO_2}^{F}\right)_z \cdot F_z}{\left(\mu_{CO_2}^{W}\right)_{SP} \cdot W_z + \left(\mu_{CO_2}^{Q}\right)_{SP} \cdot Q_z + \left(\mu_{CO_2}^{R}\right)_{SP} \cdot R_z} \tag{9}$$

This parameter is highly sensible to the emission factors attributed to the different equipment, both for the reference and the network configurations. Therefore, it has been chosen to compare the CO_2 emission of the network (Natural gas emission μ_{TR}^{F}=200,73 [g/kWh$_e$]), with the CO_2 emission of the separated production considering two possibilities. In Case 1, the emission factor of the Italian thermoelectric energy production alone, in which the effect of the renewable energy plants is not present, is considered. Therefore, for the electric energy production $\mu_{SP}^{W} = 544{,}9$ [g/kWh$_e$] and for the thermal energy production μ_{SP}^{Q}=200,73 [g/kWh$_e$]. In Case 2, the emission factor of the whole Italian generation system is taken as a reference, therefore for the electric energy production $\mu_{SP}^{W} = 381{,}37$ [g/kWh$_e$] and for the thermal energy production μ_{SP}^{Q}=200,73 [g/kWh$_e$]. This results in a higher value of CO_2 emission factor for case 1 [13]. In table 9, one may find the CO_2 emission factors for the two cases analysed.

Table 9. Emission factors

	μ^{W}_{SP} [g/kWh$_e$]
Case 1	544.9
Case 2	381.37

Table 10. EUF

	Milan	Rome	Palemo
Scenario 1	86.62%	86.08%	84.19%
Scenario 2	84.60%	82.66%	81.13%

5. Presentation and discussion of results

The dynamic simulation capabilities of the code are presented, for the city of Rome in summer, in Fig. 5 a and b. The weekly trend of thermal storage temperature is well captured and shown for Scenario 1 and 2 respectively. One may observe the daily fluctuations and the different temperature of the storage for centralised and distributed MFA.

As for the yearly behaviour of the network, in table 10, the EUF parameter has been calculated for the different configurations proposed and for the different climatic zones considered. The results shown are typical for district heating and cooling networks. A more relevant parameter to evaluate the performance of the network is TPES, which is related to the summer trigeneration. In Fig. 6 a, b, c, these results are shown.

This parameter should highlight the primary energy saving associated with the network implementation as compared to the separated production (Scenario 0). It is this Scenario 0 which influences this parameter, and this why, the network has been compared with three different separated production scenario from Best Efficiency (Case1) to lowest efficiency (Case 3). If one compares the network performance with the BAT, Fig. 6 a, none of the proposed network configurations (Scenario 1 and 2) is convenient in any of Climatic Zones chosen. When moving down to Case 2, Fig. 6 b, in which the separated production is made with the efficiencies according to the DM 2011, the network is convenient in all but one condition. This condition refers to Climatic Zone (B) which is penalized by the high needs of refrigeration in summer. If, then, Case 3 figure 6c, is considered, which could very well apply locally, all conditions present a positive value of the TPES parameter, showing the convenience of the network configuration as compared to the separated production. These results match quite well the ones in the literature.

As a general trend one may see that in all cases the Scenario 1 presents higher value of the TPES than Scenario 2, meaning that the centralized absorption chiller configuration is more efficient than the distributed absorption chillers configuration. This is due to three different aspects highlighted by the simulations. First, the MFA in Scenario 1 has a smaller size (-38%) with respect to the sum of the three distributed MFS of Scenario 2. Second, in Scenario 1 the operating fluid in the network has a low temperature, closer to the ground temperature thus reducing the heat losses in the storage and net: a reduction of 50% of losses is achieved in Scenario 1. Third and last, due to temperature fluctuations of the working fluid temperature in the net, the three distributed MFA suffer this condition presenting lower values of the COP, while the centralized MFA which is supplied directly by the CHP, does not resent them.

In Fig. 6b, one may see that the Palermo case (Climatic zone B), presents the lower values of the TPES coefficient, even negative for the Scenario 2. The absorption chillers need high temperature energy (approximately 90°C), therefore, in summer the thermal efficiency of the engine is reduced if compared with the winter case in which the working fluid temperature is lower (70°C), and the electric chillers of Scenario 0, have higher COP values with respect to the absorption chillers, Table 7. Therefore, the primary energy saving may not be achieved as was found in [11, 12].

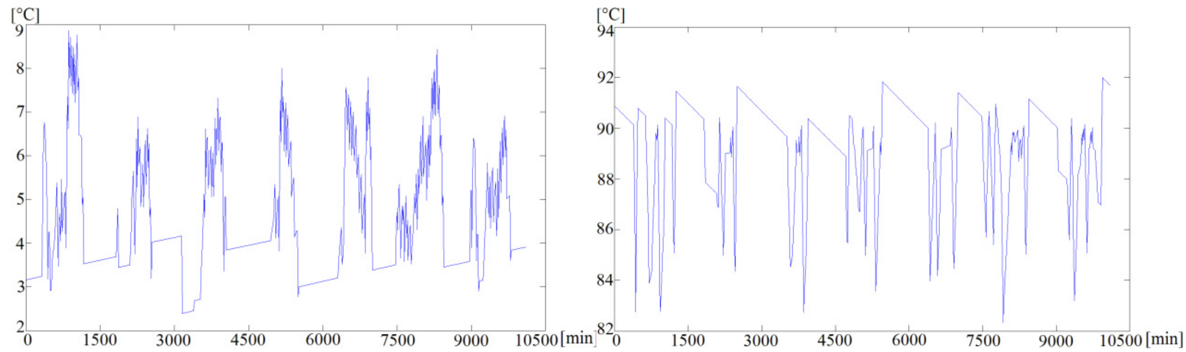

Fig. 5 Summer, Rome, thermal storage temperature: a Scenario 1, b Scenario 2

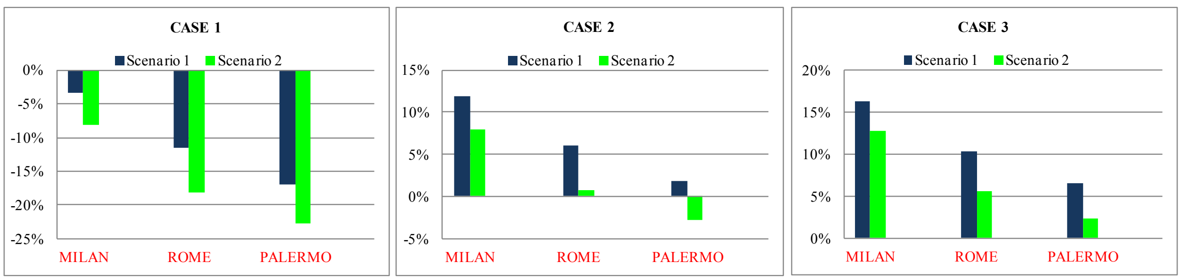

Fig. 6 a, b, c. TPES for the three cases

If one wishes to evaluate the environmental benefit of the network, it is interesting to show the difference between the network emission and the separated production emission. The TCO_2ER factor expresses this quantity as already presented in paragraph 4. The network has been compared to two different separated production systems: Case 1 takes the average electric emission factor for the thermoelectric production only, while Case 2, more performing, has the average electric emission factor of the Italian network. The thermal production emission factor is the same for all cases.

In Case 2, Fig. 7 b, there is no noticeable emission reduction ascribable to the heating and cooling network. This is due to the fact that the Italian emission factor has strongly lowered due to the penetration of the renewable energy plants. Therefore, in Case 2 the comparison is altered by the presence of virtually CO_2 emission free technologies. Case 1, instead, shows CO_2 emission reductions ranging from 20 to 30% for all climatic regions and all Scenarios, Fig. 7 a. Without surprise, Scenario 1 presents the higher emission reductions as could be expected from the higher values of the TPES parameter.

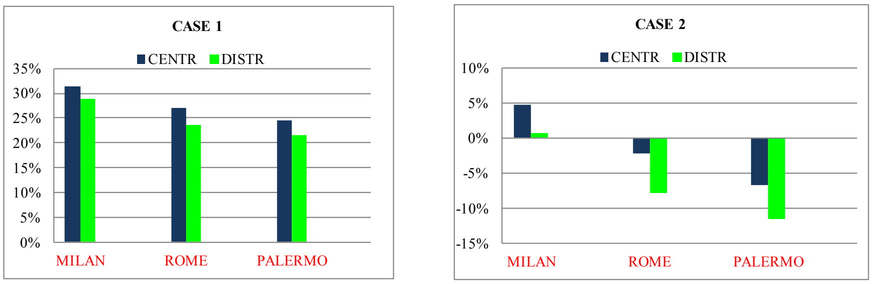

Fig. 7 a,b. TCO_2ER for the two cases

6. Conclusions and future perspectives

A code for the dynamic simulation of a micro heating and cooling network has been implemented on Simulink environment. The program includes the possibility of taking into account the variation of weather external condition, of the human presence, lighting schedule, air exchange to dynamically simulate a real behavior. A thermal storage has been included to stabilize the network operation and its response to transients.

In order to validate the code, its simulating capabilities have been tested in different Climatic Zones and the main performance coefficients have been calculated. The results found are consistent and in line with the results presented in the literature for similar cases [11, 12].

The code is now being used to simulate larger scale networks and include poli-generation possibilities.

References

[1] http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/priorities/sustainable-growth/index_it.htm
[2] Sbordone D. Martirano L. Falvo M. C. Sviluppo e implementazione di moduli in ambiente Matlab Simulink per la realizzazione di un simulatore di rete energetica distribuita. Report RdS/2012/079.
[3] AIRU. Il riscaldamento urbano. AIRU periodico 2011.
[4] Kinesis. City of Sydney decentralised energy master plan trigeneration 2010-2030. Sydney, 2012.
[5] Dr. Walid Fayad. George Sarraf. Tarek El Sayed. Simon-Pierre Monette. Unlocking the Potential of District Cooling The Need for GCC Governments toTake Action. Booz & Company. 2012.
[6] Report RSE/2009/188.
[7] Ceravolo F. Di Pietra B. Pizzuti S. Puglisi G. Neural models for ambient temperature modelling, (ISBN 978-1-4244-2306-4), 2008.
[8] RSE/2010/251.
[9] Felli M. Lezioni di fisica tecnica. Morlacchi, Roma, 1999. p. 226-231.
[10] Mazza M. Antinucci M. Brolis M. Vademecum sulle tecnologie del risparmio energetico. Agenzia per l'Energia e lo Sviluppo Sostenibile di Modena.
[11] Chicco G. Mancarella P. Assessment of the greenhouse gas emissions from cogeneration and trigeneration systems. Part I: Models and indicators. Energy 33 (2008) p.410–417.
[12] Mancarella P. Chicco G. Assessment of the greenhouse gas emissions from cogeneration and trigeneration systems. Part II: Analysis techniques and application cases. Energy 33 (2008) p. 418–430.
[13] http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni/fattori-di-emissione-per-la-produzione-ed-il-consumo-di-energia-elettrica-in-italia/view.