J. Basic. Appl. Sci. Res., 2(12)12101-12114, 2012
© 2012, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Technical and Economic Allocation of Combined Cooling, Heating and Power (CCHP) To Powering Sensitive Loads in Power System

Farhad Samaie*[1], M. H. Moradi[2]

[1]Department of Electrical Engineering, Bahar Branch, Islamic Azad University, Bahar, Iran
[2]Department of Electrical Engineering, University of Bu Ali Sina, Hamadan, Iran

ABSTRACT

In this paper, we present a hybrid and practical method for allocation of combined cooling heating and power (CCHP) generator at the bus. Firstly, network sensitive buses will be candidate for CCHP installation. At Second stage, utilizing the bus thermal coefficient, the possibility of heat selling around these buses can be calculated using the fuzzy method, then by considering the bus thermal coefficient and electrical power to heat ratio of CCHPs on the market we recommend several CCHPs for this buses. In this section, the financial benefit for investors by selling CCHP heat output is determined (Economic Analysis). In the third stage, the amount of the loss reduction and the voltage improvement due to proposed CCHPs installation using nodal pricing method is observed as financial benefit of distribution company (Technical Analysis). Finally, we obtain the suitable location of CCHP based on Game Theory and considering the Distribution Company and investors as players. The proposed method is examined in a sample distribution feeder in the city of Hamedan.

KEY WORDS: CCHP Allocation, Technical, Economic and Defense (TED) Analysis, Nodal Pricing Method, Bus thermal coefficient, Game Theory.

INTRODUCTION

With increasing the demand of electrical energy and electrical energy efficiency of small units, these units are more likely to be utilized in the distribution systems and near the consumers. These small units that are connected to the distribution system are called "distributed generation" (DG). the privatization of electricity industry, less environmental pollution, high efficiency and developing methods of electricity generating through the renewable energy are important factors for the development of these generator types.

One of the most important point that should be considered to determining the location and size of distributed generations for supplying electrical energy of sensitive consumer, is the Defense factor.

A study following the 11 September attacks suggested that a system based more on distributed generation plants may be five times less sensitive to systematic attack than a centralized power system [30].

The Blackout in 2003 in North America and reviews the main options to minimize such disruption in the future, was lead to consideration of DG And especially CCHP, to reduce vulnerability of threatening terrorist attack in power systems [31,32,33].

The use of distributed generation units has significant impact on the power systems technical and economic issues [1,2] .

A type of these power plants, is electrical and heat co-generation unit (CHP) which supplies the heating or cooling that needed for consumers through its waste heat output and increases the whole power plant efficiency up to 75% and above. Since the gas fuel is available in our country, these power plants are good substitutes for the electricity and heat generation.

The location and capacity determination of distributed generation resources are effective parameters on the technical indicators. Reduction of losses, improvement of the voltage profile and the voltage regulation are considered as significant indicators in the objective functions to optimize the location and capacity of these generators [3,4] and then these defined functions will be optimized by intelligent methods such as GA, PSO and TS and the capacity and location of DG will be determined [5,6] .

For placement and capacity determination of "CCHP", in addition to the above technical analysis, the economic analysis is usually considered. In this analysis, the investment criteria is considered to optimize the power, heat, warm water and even cold consumption on the objective function, simultaneously [7,8] .

---

* **Corresponding Author:** Farhad Samaie, Department of Electrical Engineering, Bahar Branch, Islamic Azad University, Bahar, Iran, Phone **:** +98 918 3189275, Email**:** farhadsamaie@gmail.com

The CCHP installed on the distribution network will change it from passive to active network, and improves the network losses, voltage regulation and profile [10,11] . The Improvement of this technical indicators are considerable by "nodal pricing methods" at the electrical energy price of buses to which CCHP is connected to them, In other words, the CCHP installation is effective at the nodal pricing of buses [9] . In addition to improving the technical indicators that are desirable for distribution companies, CCHP installation will created the opportunity to use the heating and warm water for consumers around the bus, and that is favorable to CHP investors. Allocation and capacity determination of "CCHP" in a way that both technical indicators are improved and while most profits produces are the practical challenges facing researchers, that depends on the strategy and policy of players in this activity, the distribution companies and investors.

The researchers have shown interest in using the "Game Theory" in recent years . Generally, where a group of individuals or firms compete with each other or they cooperate in a team, the Game Theory can be used to model competition between them. Song Yiqun [12] using non-cooperative Game Theory and Nash-Stackelberg equilibrium, a new method for determinating the power market is presented. Lance B.cunningham [13] also using Game Theory and Corn out equilibrium, a way to model the transmission line congestion in the electricity market, is presented. Lance B.cunningham [13] cooperative Game Theory has been used, and the consumers of heat and power are considered as members of the coalition to achieve higher profits by reducing investment and increasing the efficiency of co-generating electricity and heating (CCHP).

In this paper a hybrid method has been provided to CCHP allocation on bus. In this method using cooperative Game Theory, investors and distribution companies have been used as the coalition members to achieve higher profits and improved technical indicators of network. The proposed hybrid method has Three stages as follows :

Firstly, network sensitive buses are candidates for CCHP installation. At Second stage, In order to economic analysis, with the investigation of heat consumers around the bus, the bus thermal coefficient that indicates the heat selling possibility of the bus will be extracted by introduced fuzzy function. Then, with regard to heat capacity and electrical energy to heat ratio in the CCHP market, several CCHPs will be specified for the candidate buses, that installation of each CCHP, brings different profit for the investor .

In the third stage, In order to technical analysis, the effect of proposed CCHP installation on the technical indicators of network, same reducing losses and improving voltage profile and regulation by nodal pricing method, in the form of profits for distribution companies is calculated. And since the distribution companies and investors considering as players, the CCHP capacity and its electrical power to heat ratio considering as the players' strategies, the suitable CCHP is determined from the proposed CCHPs by Game Theory approach. This paper is arranged as follows :

Game theory approach is described in section 2; the fuzzy bus thermal coefficient for economic analysis and the nodal pricing method for technical analysis are defined in sections 3 and 4, respectively. The optimization method is described in Section 5.and finally the case study results for the sample feeder in the city of Hamadan are provided.

Game Theory approach

In the game theory, a game is a set of rules known to all players that will determine any of their choices and the consequences of every choice.The normal form of game represents the number of players, set strategies, and the payoff functions of each player. Assuming there are n players, a set of players is :

$$N = \{1,2,\dots,n\}$$

The decisions set that player **i** can get it is named "strategy space of player **i** " and is shown as follows:

$$S_i = \{s_{i1}, s_{i2}, \dots, s_{imi}\}$$

Since there are **n** players, the strategies of all players are:

$$S = \{S_1, S_2, \dots, S_n\}$$

Where :

S_{ij} : The jth strategy of player i .
m_i : The total number of strategies .
s_{ij} : The jth strategy of player "i" in the strategy set .

On the other hand, payoff function for player "**i**" shows the outcome or result (including profit, utility, etc.) that player "**i**" will achieve at the end of the game. This payoff will depend on the chosen strategies by all players, and is shown as follows:

$$u_i = u_i(s_{1j}, s_{2j}, \dots, s_{nj})$$

That $s_{ij} \in S_i$, shows jth strategy of player "i" in the strategy set (Si). Also the combination of all players strategy is called strategy profile, and is shown as follows:

$$s_j = (s_{1j}, s_{2j}, \ldots, s_{nj})$$

Thus the normal form of an n-persons game, represents the player's strategy space ($S_1,\ldots,S_n$) and their payoff function ($u_1,\ldots, u_n$), is shown as follows [22].

$$G = \{S_1,\ldots,S_n ; u_1,\ldots,u_n\}$$

Osborne, M.J. and Rubinstein [21] have shown that the solution of "Game" is a continuous selection of equilibrium strategies, the Nash equilibrium is used usually. In this equilibrium:

$$\forall i, \forall s_{-i} \in S_{-i} \quad U_i(s_i, s_{-i}) \geq U_i(s'_i, s_{-i}) \qquad (1)$$

Where **:**

s_i : Nash equilibrium strategy of player i

s'_i : None- Nash equilibrium strategy of player i

s_{-i} : Other players’ strategy at the Nash equilibrium, That $s_i \in S_i$ is the Nash equilibrium strategy of player i and $s'_i \in S_i$ is None -Nash equilibrium strategy of player i.

The Nash equilibrium is a condition achieved by a set of strategies, and the players' decision to deviate from such state will reduce the profit. Search to find the equilibrium point includes the following steps:

1. Forming a set of possible strategies, except dominant strategies, (the s'_i strategy of player **i**, so that fulfils the following condition [21]:

$$\forall s_{-i} \in S_{-i} \quad U_i(s_i, s'_{-i}) \geq U_i(s'_i, s'_{-i}) \qquad (2)$$

2. Search to find the equilibrium point.

the Nash equilibrium is determined with regard to the 1. In terms of theory, there will be many equilibrium points, which in [21] some methods are presented for reducing the number of equilibrium points.

3. Considering of the rationality and the possibility of organized coalition for players.
4. Chosen methods to organize coalitions and the distribution of excess profits in the coalition participants.

If there is a possibility of a coalition among the players, the possible strategies of coalition may increase the dimensions of problem significantly.

Finally, the output of this method is semi-optimal path for all companies and their coalitions with regard to competitors’ strategy. In this paper, in order to allocate and determine the capacity of CCHP "The Static Game with complete information" is used. In this method, players are :

- Electric Power Distribution Company State (player A)
- Investors (player B)

The possible strategies :

- The electrical power to heat ratio of different CCHP technologies which are given in Table1 [20] .
- Choose the capacity of CCHP$_s$ that has been considered 0.5 and 1 MW in this paper.

Table 1. characteristics of CCHP technologies

technology	steam turbine	gas engine	gas turbine	micro turbine	Fuel cell
power to heat ratio	0.1 - 0.3	0.5 - 1	0.5 - 2	0.4 - 0.7	1-2

By obtaining the Nash equilibrium point, the suitable location and capacity of the CCHP generator will be achieved for installing in the bus network .

Economic Analysis Using The Bus Thermal Coefficient

The power at bus "**i**" is :

$$P_{T_i} = P_{e_i} + P_{h_i} \qquad (3)$$

And

$$P_{h_i} = \sum_{j=1}^{n} P_{h_{ij}} \qquad (4)$$

Where **:**

P_{e_i} : Active power consumption at bus "**i**".

P_{h_i}: The electrical equivalent of heat selling possibility at bus "**i**".

P_{T_i}: The total power.

In the above equations, P_{hi} is supplied by CCHP source that only connected to bus "**i**", and if it will be supplied by other buses, heat and cooling loss, eliminate this possibility while Pei can be supplied by other buses of network . The optimization problem can be divided into two parts :

- Optimization with regard to consumption of P_{ei} for each bus of network that can be also supplied by generators at other buses .
- Optimization with regard to P_{hi} the sale of heat (equivalent to electric power) for each bus of network that is supplied by generator at the same bus only.

Bus Thermal Coefficient (BTC) :

Indicates the possibility of selling steam and warm water to Defense Sensitive buses, and with regard to the consumers around the bus is calculated as follows :

$$BTC_i = \frac{P_{h_i}}{1\,MW} \quad , \quad BTC_i \geq 0.1 \qquad (5)$$

Where :

$P_{h_{ij}}$: The possibility of heat selling (equivalent to electric power) to the consumer "j" at bus " i .

N : Total number of consumers around each bus .

BTC_i : Bus thermal coefficient of bus "i".

$Q_{h_{ij}}$: The heat consumption (equivalent to electric power) of consumer "j" at bus"i".

β : Type of consumer.

d : The distance between the heat consumer and power plant.

x : Coefficient of CCHP technology that depends on the conditions that heat be generated by CCHP.

ψ : Fuel delivery coefficient .

The thermal coefficient of bus will be achieved by normalization the possibility of heat selling to 1MW.Finally, the buses with higher amount of BTC are eligible for CCHP installation that will be considered in the calculations of objective function optimization.

P_{hi} is the function of effective coefficients phase sharing (minimum) of heat selling and will be expressed by equation (6) :

$$P_{h_i} = \sum_{j=1}^{N} P_{h_{ij}} = \sum Q_{h_{ij}} \times f_{ij}(\beta \cap d \cap x \cap \Psi) \qquad (6)$$

Calculation of β : According to the National Building Regulations in Iran [23], there are four groups of building types, A to D. This grouping is based on the following three factors:

- continuating the using of building during the day and the year.
- The temperature difference between the interior and exterior of the building.
- The significance of stabilization of temperature of indoor spaces.

β is determined based on the user type in Table 2. Higher β indicates more possibility of heat selling to the consumer.

Table 2. Buildings classification according to the National Building Regulations

sample	β	user type
Hospitals, hotels(4 and 5stars), industries with the heating consumption for the generation process (cement, steel, melted metals, sugar, food, greenhouseTown)	**1**	A
Integrated academic and large schools (with dormitory), skyscrapers, large residential complexes (with central heating systems).	**0.75**	B
Stores, factories (heating and sanitary use only), international airport	**0.5**	C
Places of business (shopping centers), offices	**0.25**	D
spread consumers that can not using of central heating systems	**0**	All cases

Amount of heat consumption (equivalent to electrical power) Q_{hij}:

The calculation of the energy needed for different loads (various applications) according to references [15,16], has been done for 1000 m^2 infrastructure, and this point is considered that, Hamadan city uses from natural gas of the main pipeline with special heating value of 9434 Kcal/m^3 or 1060 Btu / ft^3. For example, in multi-unit residential building that use the central heating systems (for 1000 m^2 infrastructure)

A) The warm water consumption : 231.84 (kw)
B) The heat consumption for heating : 117.16 (kw)
Total heating and warm water consumption of different buildings is shown in Fig.1 .

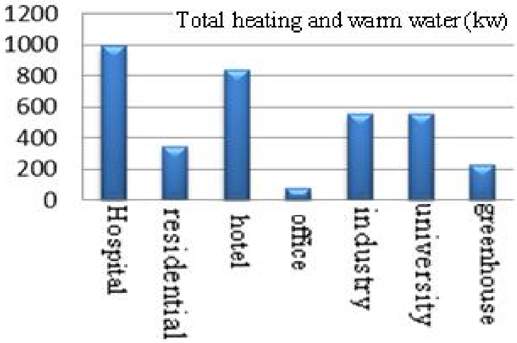

Fig. 1. Q_{hij} for different consumers, with infrastructure of 1000m^2

The distance between heating consumer and power plant (d) : The other issue that should be considered at heating distribution is the distance between heating consumer and power plant, so that by increasing the distance, heat selling possibility will be reduced while the transport cost will be increased. In other words, the bus thermal coefficient (fitness) is proportional to the inverse distance :

$$f(d) \approx \frac{k}{d}$$

That, **d** is the difference between heating consumer and power plant and coefficient **k** is depends on the heat transferring system that achieves based on the practical results. The possibility of heat and warm water transferring to the different distances is expressed by following fuzzy membership function (Fig.2) :

$$\overline{f(d)} = \begin{cases} 1 & d < 333 \\ \dfrac{1050 - d}{717} & 333 \le d \le 1050 \\ 0 & d \ge 1050 \end{cases}$$

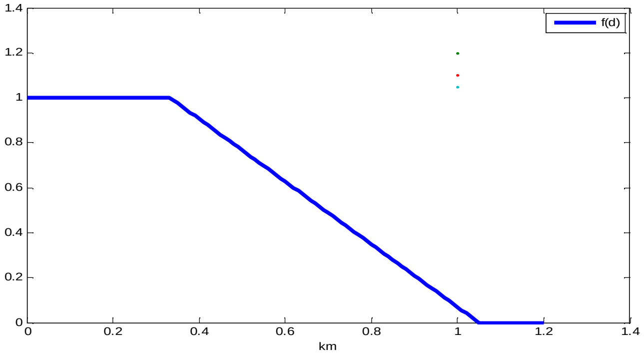

Fig. 2. The fuzzy digit corresponding f(d)

Fuzzy membership function : fuzzy digit $f(d)$ in parametric mode is the regular pair of ($\overline{f(d)}$, $\underline{f(d)}$) which must satisfy the following requirements :

1. $\underline{f}(d)$ Continuous boundary function from left.
2. $\overline{f}(d)$ Continuous boundary function from right.
3. $\underline{f}(d) \le \overline{f}(d)$, $0 \le f(d) \le 1$

Determination of Technology Coefficient (x) : This ratio expresses which technology is used to generate electricity and heat in the CCHP (Table 3). Coefficients x_1 to x_5 can be determined according to the CHP thermal output. For example, gas turbine technology, which provides heat, warm water, LP and HP steam, has highest coefficient of **x** . In some of the CHP units, a variety of Absorption chillers [27], Adsorption chillers [28], and Desiccant dehumidifiers systems in humid areas [29] can be used and they changed to CCHP units . In these systems the technology coefficient will be raised.

Table 3. various CCHP technologies

Technology	**steam turbine**	**reciprocating engine**	**gas turbine**	**micro turbines**	**Fuel cell**
Typical power to heat ratio	0.1-0.3	0.5-1	0.5-2	0.4-0.7	1-2
The Power electrical efficiency(HHV)	15-38%	22-40%	22-36%	18-27%	30-63%
Total efficiency(HHV)	80%	70-80%	70-75%	65-75%	55-80%
Using of output heat	LP- HP steam	LP- HP steam	Warm water, LP steam	Heating,warmwater, LP steam	Warm water, LP- HP steam
$\mathbf{X_{CHP}}$	0.20	0.45	0.9	0.35	0.70
$\mathbf{X_{CCHP}}$	0.25	0.5	1	0.5	0.75

fuel delivery Coefficient (ψ) : Since the natural gas is used as the main fuel for these power plants and gas lines have three pressures,1000 PSI for gas transmission, 250 PSI and 60 PSI for gas distribution in the cities; therefore, considering the consumers distance around each bus from the transmission and distribution gas lines (d), and the experimental results obtained from the gas company, the corresponding fuzzy digits ($\psi(d)$) with different gas pressures is shown in Fig.3 .

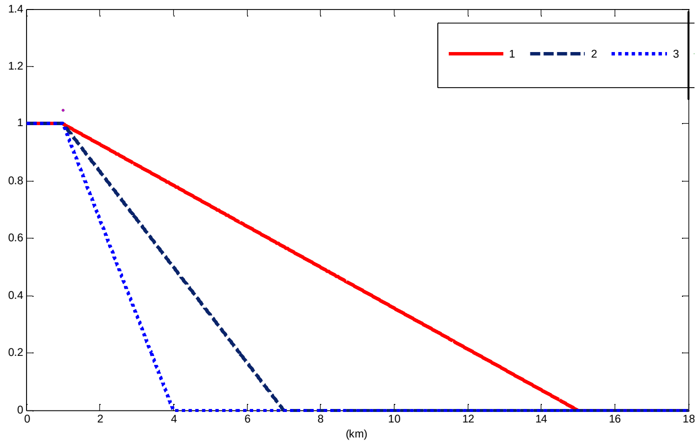

Fig. 3. fuzzy digit corresponding to $\psi(d)$ for the pressure of (1)1000PSI, (2) 250PSI and (3) 60PSI

Finally through determining of bus thermal coefficient, the amount of saving the thermal cost of each bus (with regard to government support in this area [19]) will be obtained after CCHP installation as follows :

$$C_{H_i} = BTC_i \times \Delta t_i \times \lambda_H \qquad (7)$$

Where :

C_{Hi} : saving the thermal cost after CCHP installation, $\frac{\$}{year}$

λ_H : The cost of per "MWh" heating, is equal to7.2 $, since the project of "targeted subsidies" is executed.

Δt_i : 8760 hour in a year.

Technical Analysis Using The Nodal Pricing Method

The distributed generation resources in the network will change the power flow and losses on two-level of transmission and distribution networks. In many tariffs plants in distribution level, use from the equally share of losses cost for consumers, that discourages the consumers for the CCHP installation [24]. For solving this problem

we can utilize the "Nodal Pricing Method". The price of electricity in the nods indicates the marginal price of electricity in the network buses [9], in this paper the characteristics of formulas are defined as follows :
Marginal losses coefficient (MLC) is the active power losses network change (P_L) due to change in production or consumption of the active power (P_{e_i}) and the reactive power (Q_{e_i}) in bus "**i**" that defined as follows [17] :

$$\rho_{P e_i} = \frac{\partial P_L}{\partial P_{e_i}} \qquad (8)$$

$$\rho_{Q e_i} = \frac{\partial P_L}{\partial Q_{e_i}} \qquad (9)$$

Where :
$\rho_{P_{e_i}}$: Marginal losses coefficient of active power at the bus "i".
$\rho_{Q_{e_i}}$: Marginal losses coefficient of reactive power at the bus "i".
The medium point between generation and transmission levels is called "power supply point" (PSP) . If "λ" is the price of active power in PSP in $\frac{\$}{MWh}$ and if the active and reactive power consumption at bus "i" change as P_i and Q_i respectively and no congestion exists in the distribution network, then we can calculate the nodal pricing for active and reactive power as follows **:**

$$N_i^a = \lambda + \lambda . \rho_{P_{e_i}} = \lambda (1 + \rho_{P_{e_i}}) \qquad (10)$$

$$N_i^r = \lambda . \rho_{Q_{e_i}} \qquad (11)$$

The price of electrical bill without CCHP installation on the period Δt will be obtained as follows :

$$C_i^{no-CCHP}(P_{e_i}, Q_{e_i}) = (N_i^a(P_{e_i}, Q_{e_i}) \times P_{e_i} + N_i^r(P_{e_i}, Q_{e_i}) \times Q_{e_i}).\Delta t \qquad (12)$$

And the total of it for each feeder is equal to :

$$C_{total}^{no-CCHP} = \sum_{i=1}^{N} C_i^{no-CCHP}(P_{e_i}, Q_{e_i}) + (\lambda \times P_L).\Delta t \qquad (13)$$

CCHP installation decreases the distribution losses, and so the nodal pricing will be reduced [26] . The price of electrical bill with CCHP installation on the period Δt at bus "**i**" will be obtained as follows :

$$C_i^{CCHP}(P_{e_i}, Q_{e_i}) = \{(N_{i,CCHP}^a(P_{e_i}, Q_{e_i}) \times (P_{e_i} - P_{CCHP_i}) + N_{i,CCHP}^r(P_{e_i}, Q_{e_i}) \times (Q_{e_i} - Q_{CCHP_i})\}.\Delta t + \{C_{(CCHP)} \times P_{CCHP_i}\}.\Delta t \qquad (14)$$

And the total of it for each feeder is equal to:

$$C_{total}^{CCHP} = \sum_{i=1}^{N} C_i^{CCHP}(P_{e_i}, Q_{e_i}) + (\lambda \times P_{L,(CCHP)}).\Delta t \qquad (15)$$

Where :
N_i^a : Nodal pricing of active power without CCHP
$N_{i,CCHP}^a$: Nodal pricing of active power with CCHP
N_i^r : Nodal pricing of reactive power without CHP
$N_{i,CCHP}^r$: Nodal pricing of reactive power with CCHP
Q_{e_i} : Reactive power consumption at bus i
P_{CCHP_i} : Active power supplied by the CCHP at bus i
Q_{CCHP_i} : Reactive power supplied by the CCHP at bus i
$C_{total}^{no-CCHP}$: Price of electricity supplied by the network without CCHP
C_{total}^{CCHP} : Price of electricity supplied by the network with CCHP
$C_{(CCHP)}$: Price of electricity supplied by CCHP.

$P_{L,(CCHP)}$: Active power losses by considering CCHP.

P_L: Active power losses without CCHP.

The CCHP is intended as a negative load at its bus and to simplify the calculations assume that Q_{CCHPi} and P_{CCHPi} are zero at all buses except that DG is installed **.**

$$P_{CCHPi} = \begin{cases} 0, i \neq i_{best} \\ P_{CCHPi} \ , i = i_{best} \end{cases}$$

And

$$Q_{CCHPi} = \begin{cases} 0, i \neq i_{best} \\ Q_{CCHPi} \ , i = i_{best} \end{cases} \qquad (16\ )$$

The larger difference “$C_{total}^{no-CCHP} - C_{total}^{CCHP}$ ”leads to the distribution company profit increases by DG installation,and its formulation will be as follows :

$$T = C_{total}^{no-CCHP\,(a)} - (C_{total}^{CCHP\ (b)} + C_{total}^{CCHP\ (c)}) \qquad (17)$$

Where:

T : Benefits of technical indexes improvement (for the distribution company)

$C_{total}^{no-CCHP\,(a)}$: Price of electricity supplied by the network without CCHP

$C_{total}^{CCHP\,(b)}$: Price of electricity supplied by the network with CCHP

$C_{total}^{CCHP\,(c)}$: Price of CCHP electricity .

The voltage rise at the CCHP connection point and its impact on the voltage profile needs to be considered [18] .

Also the voltage of each bus should be limited within the minimum and maximum defined permissible range in the distribution network; therefore, CCHP should be installed with the voltage condition in accordance relation (18), so that the bus voltage will be limited within its permitted range.

$$V_i^{\min} \leq V_i \leq V_i^{\max}, \quad i = 1,\dots,N_n \quad (18)$$

Where:

V_i : Voltage at bus "**i**"

V_i^{min} : Minimum permitted voltage at bus "**i**"

V_i^{max} : Maximum permitted voltage at bus "**i**"

N_n : Number of network buses

Technical, Economic and Defense (TED) Algorithm

Block diagram of the proposed algorithm for optimal allocation of CCHP is as follows (Fig.4):

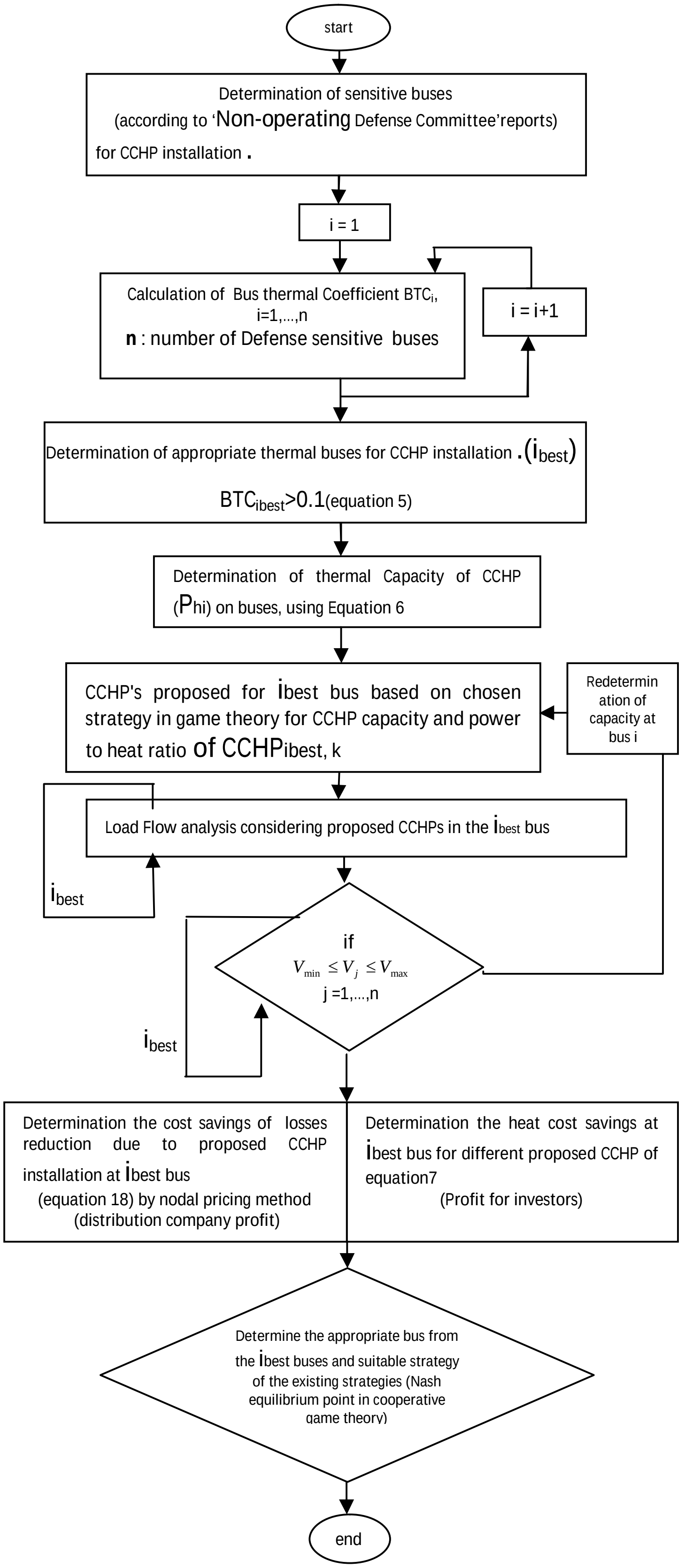

Fig. 4. Block diagram of CCHP Placement algorithm

Where :

CHPibest,k : The CHP installed at bus i_{best} that follows the k strategy, (k : 1,..., k_{max}) .

Case Study

In this part, one of the 20 KV Hamadan distribution feeders with 63 buses has been studied . This feeder is fed by Hamadan 63/20 kv station 2 (Fig.5) . Specifications of this feeder are presented in table 4 :

Table 4. Specifications of studied feeder

Length (KM)	Peak load of current (A)	P_{max} (MW)	Price of electricity supplied by the network (λ) US $ / MWh[25]
12	80	2.3	50

The system has been simulated for a fixed time in this paper . With regard to the reciprocating engines CCHP type, and based on cost of CCHP in table 5, and assuming 75% efficiency achieved through the placement method in this paper, the cost of electricity supplied by CCHP is equal to 53 $ for a megawatt hour .

Table 5. Cost of used CHP

the investment of installation price $\frac{US\ \$}{KW}$	maintenance and operation cost $\frac{US\ \$}{KWh}$	operation time $\frac{h}{year}$	equipment life (year)
900-1500	0.5-2	8760	50

According to consumers information, the large thermal loads of feeder are installed on buses : 1, 5, 16 and 22 . That their specifications are given in table 6.

Table 6. Thermal specifications of major consumers buses

Heat and warm water consumption (KW) (Pis)	consumer infrastructure (m^2)	Type of Consumption located around each bus	Bus Number
3040	37840	Load 1,(office) C_1	1
5619	27825	Load 2, (university)C_5	5
890	11110	Load 16, (office) C_{16}	16
1000	13300	Load 22,(Residential) C_{22}	22

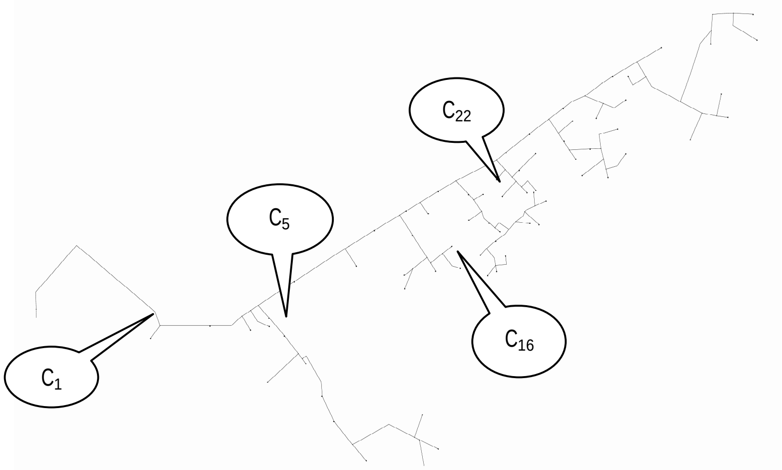

Fig. 5. The Sensitive consumers (on feeder)

The buses in which heat selling possibility are available and $BTCi \geq 0.1$ are suitable for CCHP installation. In these buses the CCHP capacities are calculated using fuzzy method (Table 7) .

Table 7. Determination of CCHP thermal capacity for candidate buses

CCHP capacity based on buses thermal capacity (MW)	BTC	Thermal capacity of bus (kw) $P_{Sij} = Pis \times f(\beta, d, x, \Psi)$	Bus number
0.7	0.7	$3040 \times (0.25 \cap 1 \cap 0.75 \cap 1) = 760$	1
1.4	1.4	$5619 \times (0.75 \cap 1 \cap 0.5 \cap 0.25) = 1404$	5
0.22	0.22	$890 \times (0.25 \cap 1 \cap 0.75 \cap 1) = 220$	16
0.25	0.25	$1000 \times (0.75 \cap 1 \cap 0.75 \cap 0.25) = 250$	22

- Thermal benefit calculation :

In this stage we assume that CCHPs installed on the all proposed buses (1, 5, 16, 12) have 0.5 &1MW capacities and the electrical power to heat ratios is 0.7 and 1. Then for each case the heating cost savings is calculated using equation 7 that is shown in table 8 .

Table 8. benefit of the heating consumers in the different game strategies

Power / Heat Ratio = 1			
Bus number	Electric capacity (MW)	supplied Heating (MW)	Heat cost saving at each bus (investor profit) $\frac{\$}{year}$
1	1	0.7	44150
	0.5	0.5	31536
5	1	1	63072
	0.5	0.5	31536
16	1	0.22	13875
	0.5	0.22	13875
22	1	0.25	15768
	0.5	0.25	15768
Power / Heat Ratio = 0.7			
1	1	0.7	44150
	0.5	0.7	44150
5	1	1.4	88300
	0.5	0.71	44781
16	1	0.22	13875
	0.5	0.22	13875
22	1	0.25	15768
	0.5	0.25	15768

-Technical indicators benefit calculation :

CCHP installation will improve the network technical indicators, and this improvement is considered as benefit for electrical distribution company. At first we doing Load Flow and then using the nodal pricing for candidate buses. These prices are available for the CCHP candidate buses before and after installation (for 0.5 MW and 1 MW) in table 9, also it is assumed that CCHP works with "unit power factor", this means it will produce the (real) active power only. As it is shown in table 9 the active nodal price of each bus will be reduced essentially, when CHP is present.

Table 9. nodal pricing of active power obtained by fuzzy bus thermal coefficient for fixed loads without and with CCHP

Bus number	**CCHP capacity based on bus thermal coefficient (MW)**	**Nodal pricing of active power at buses without CCHP (US $ / MWh)**	**Nodal pricing of activepower at buses with CCHP (US $ / MWh)**
1	1	51.445	50.945
	0.5	51.475	51.175
5	1	51.015	50.965
	0.5	51.44	51.24
16	1	51.14	50.99
	0.5	51.41	51.31
22	1	51.485	51.035
	0.5	51.505	51.4

By CCHPs installation with the capacities mentioned, using formulas 8 to 17,and table 9, the profits of losses reduction for the CHP buses candidates will be calculated .

By considering CCHP installed at bus 1 and doing load flow analysis, the new calculated losses, the amount of electrical energy supplied by the CCHP and network will be determined and the cost of CCHP and network electricity will be calculated (columns 5 and 6, Table 10). The CCHP installation benefits is obtained from the equation {a-(b + c)} of column 7 in the table 10. The column 7 indicates the benefits of CCHP installation which is desirable for Distribution Company.

Table 10. Distribution company profit produced by the generator installed at each bus using the nodal pricing method

Bus number	**cost of network electricity without CCHP**[1] **(a)** $\frac{\$}{year}$	**CCHP capacity (MW)**	**losses (MW)**	**cost of network electricity (b)** $\frac{\$}{year}$	**cost of CCHP electricity (c)** $\frac{\$}{year}$	**Distribution company profit a-(b+c)}{** $\frac{\$}{year}$
1	1007400	1	0.189	341640	464280	201480
		0.5	0.235	754236	232140	21024
5		1	0.193	516840	464280	26280
		0.5	0.248	759930	232140	15330
16		1	0.198	519030	464280	24090
		0.5	0.262	766062	232140	9198
22		1	0.207	522972	464280	20148
		0.5	0.281	774384	232140	876
1.The total losses of network will be 0.313 MW without CCHP installation.						

- Game theory for Optimal selection

In the proposed method, the distribution company and investors are players A and B respectively, the strategies which these two players can choose, are electrical power to heat ratio (0.7or 1) and electrical capacity (0.5 MW or 1 MW) of CCHP. By installation of specified CCHPs at the candidate buses through the above strategies, the benefit of consumers and distribution companies (payoff (wining) for each player) will be determined from table 8 and 10 that are shown in Table 11. We can specify the Nash equilibrium point in static game with above complete information from table 11 . This point chosen indicates that benefits of both players are maximum and every player attempting to change these selection will lead to detriment of other players and the whole set. According to Table 11, it can be seen that the choice of strategy A_3 (CCHP installed capacity of 1MW and power to heat ratio of 0.7) at bus 5, the Nash equilibrium of this game is obtained that in this point the player gains A and B are respectively 26,280 and 88,300 dollars per year.

Table 11. The payoff (wining) amount for players with different Strategies

		Player B			
		B_1	**B_5**	**B_{16}**	**B_{22}**
Player **A**	A_1	201480^+, 44150	26280 , 63072	24090^+,13875	20148^+,15768
	A_2	21024 , 31536^+	15330 , 31536^+	9198, 13875	876 , 15768
	A_3	201480^+, 44150	26280^+, 88300^+	24090^+,13875	20148^+,15768
	A_4	21024 , 44150	15330 , 44781^+	9198 , 13875	876 , 15768

CONCLUSION

In this paper, based on Technical, Economic and Defense (TED) Analysis, a new method was proposed for the allocation of Combined Cooling, Heating and Power (CCHP) for the bus.

The CCHP installation in the distribution network improves technical indicators such as reduced losses, improved voltage profile and voltage regulation for the distribution company's profit ability and furthermore creations possibility of heat selling around the bus and profit ability for the investor.

Here, the distribution companies and investors are considered as players and capacity and power to heat ratio as the strategies of the players. Then using the Nash equilibrium, the equilibrium point is determined by two players that this point is maximum for each player and changing this point by one of the players causes to decrease another player gain.

The investor's benefit obtained from the heat selling that generated around the bus and profits of distribution company due to the technical indicators improvement using the nodal price change that has been calculated before and after installation of CCHP.

Finally, the presented method is applied on the sample feeder in the city of HAMADAN and the optimal location of CCHP is determined. The results are included to show the validity and efficiency of the new technique.

REFERENCES

1. M.H.Moradi, M. Abedini, A Combination of Genetic Algorithm and Particle Swarm Optimization for Optimal DG location and Sizing in Distribution Systems, Int. Journal of Electrical Power and Energy Systems (34) 2012, pp 66-74 .

2. T. Ackermann, G. Andersson, L. Soder. (2001). Distributed generation : a definition, Electr. Power Syst. Res. 57 (3) 195–204.

3. Mithulananthan N, Oo Than, Van Phu Le. (2004). Distributed generator placement in power distribution system using genetic algorithm to reduce losses. TIJSAT ;9(3):55–62.

4. Griffin T, Tomosovic K, Secrest D, Law A. (2000). Placement of dispersed generations systems for reduced losses. In: Proceedings of the 33rd Hawaii international conference on sciences, Hawaii .

5. M.H.Moradi, M. Abedini , A Combination of GA and PSO for Optimal DG location and Sizing in Distribution Systems with Fuzzy Optimal Theory, International Journal of Green Energy, 2011, In press.

6. K. Nara, Y. Hayashi, K. Ikeda, and T. Ashizawa, (2001). Application of Tabu Search to optimal placement of distributed generators, Proceedings of the IEEE Power Engineering Society, vol. 2, pp. 918-923, February.

7. G. Bidini, U. Desideri, S. Saetta, P. ProiettiBocchini, 1998 . Internal combustion engine combined heat and power plants: case study of the university of Perugia power plant, Appl. Therm. Eng. 18 (6) 401–412.

8. A.C. Caputo, M. Palumbo, F. Scacchia, (2004). Perspectives of RDF use in decentralized areas: comparing power and co-generation solutions, Appl. Therm. Eng. 24 (14–15) 2171–2187.

9. R.K. Singh, S.K. Goswami. (2010). Optimum allocation of distributed generations based on nodal pricing for profit, loss reduction,and voltage improvement including voltage rise issue. Electrical Power and Energy Systems 32 . 637–644 .

10. Viawan Ferry A, SanninoAmbra, DaalderJaap. (2007) . Voltage control with on-load tap changers in medium voltage feeders in presence of distributed generation.Electr Power Syst Res ;77:1314–22.

11. Repo S, Laaksonen H, JarventaustaPertti, HuhtalaOsmo, Mickelsson Mikael. (2003) . A case study of a voltage rise problem due to a large amount of distributed generation on a weak distribution network. In: Proceedings of 2003 IEEE Bologna power tech conference, vol. 4. Bologna, Italy .

12. Song Yiqun, HouZhijian, Wen Fushuan, Ni Yixin, Wu F.F. (2002). Analysis of marketpower in oligopolistic electricity market based on game theory", power systems and communications infrastructures for the future, Beijing, September .

13. Lance B.cunningham, Ross baldick, Martin L. Baughman. (2002) . Anempiricalstudy of applied game

theory: Transmission constrained cournot behavior. IEEE transactions on power systems, Vol.17, No.1,February.

14. V.Neimane ,A.Sauhats, G.Vempers, I.Tereskina, G.Bockarjova. (2010). Allocating Production Cost at CHP Plant to Heat and Power using Cooperative Game Theory “ IEEE Bucharest Power Tech Conference, June 28th – July 2nd, Bucharest, Romania.

15. ASHREA handbook of fundamental. (2005). the American society of heating, refrigerating and air–conditioning engineers, inc.

16. tabatabaie, seyed mojtaba. (2008). Computing facility construction .

17. Mutale J, Strbac G, Crucis S, Jenkins N. (2000). Allocation of losses in distribution systems with embedded generation. IEE Proc Gen TransmDistribut;147(1), 7–12.

18. Viawan Ferry A, SanninoAmbra, DaalderJaap. (2007). Voltage control with on-load tap changers in medium voltage feeders in presence of distributed generation.Electr Power Syst Res;77:1314–22.

19. D.W.Wu, R.Z. Wang. (2006). Combined cooling, heating and power: A review “. Progress in energy and Combustion Science 32, 459- 495.

20. Catalog of CHP Technologies. (2008). U.S. Environmental Protection Agency(EPA), Combined Heat and Power Partnership, Arlington, Virginia 22209 .

21. Osborne, M.J. and Rubinstein, A. (1994). A Course in Game Theory , MIT Press(Chapters 13, 14, 15) .

22. A.Souri. (2008). Game Theory and Economic Applications “,Department of Economic Sience, Tehran, Iran, Nore Elm Entesharat .

23. 19th section. (2009). National Building Regulations In Iran, Tehran, Iran .

24. A.Jalali, H. zekri. (2011). Allocation of losses costs in distribution networks in the presence of distributed generation using nodal pricing method ,the second electrical energy saving conference,Ahvaz ,Iran .

25. M.H.Moradi, F.Samaie. (2011). Optimal Allocation of Combined Heat and Power (CHP) in Hamedan City . Research Project, research committee of HAMADAN power distribution company.

26. Sotkiewicz Paul M, Mario Vignolo J. (2006). Nodal pricing for distribution networks: efficient pricing for efficiency enhancing DG. IEEE Trans power Syst ;21:1013–4.

27. Srikhirin P, Aphornratana S, Chungpaibulpatana S. A review of absorption refrigeration technologies. Renew Sustain Energy Rev 2001;5:343–72.

28. Wang R, Wang L. Adsorption refrigeration-green cooling driven by low-grade thermal energy. Chin Sci Bull 2005;50(3):193–204.

29. Energy and Environmental Analysis, Inc. Market potential for advanced thermally activated BCHP in five national account sectors. May 2003.

30. WADE (www.localpower.org). World survey of decentralized energy. 2004.

31. Ackermann T, Andersson G, So¨ der L. Distributed generation: a definition. Electric Power Syst Res 2001;57:195–204.

32. COGEN Europe (www.cogen.org). A guide to cogeneration. March 2001.

33. WADE (www.localpower.org). The real benefits of decentralized energy.