CASE-BASED REASONING APPROACH FOR COGENERATION PLANT DESIGN

José Alexandre Matelli[1,2] (UFSC), Edson Bazzo[1] (UFSC), Jonny Carlos da Silva[1] (UFSC)

[1]Campus Universitário, Trindade, 88040-900, Florianópolis, SC
[2]matelli@labcet.ufsc.br

The paper deals with the design problem of natural gas cogeneration systems. Despite its complexity, this design problem subjected to several constraints is properly solved by humans, which suggests the use of artificial intelligence (AI). Moreover, the design process is strongly based on knowledge that experts have in a domain, so that the AI techniques known as knowledge-based systems (KBS) are a well-suited approach for the cogeneration plant design. Case-based reasoning (CBR) is one of the most important KBS techniques. In this work, the basic concepts of CBR technique and a preliminary CBR scheme for cogeneration plant design are presented.

Cogeneration, Design, Natural Gas, Case-based Reasoning.

1. INTRODUCTION

The design of a cogeneration plant is a synthesis problem subjected to thermodynamics constraints which includes location and sizing of components – heat exchangers, reciprocating internal combustion engines, gas turbines, chillers, Heat Recovering Steam Generators (HRSG), etc – in order to meet power and thermal energy loads. Despite its complexity, the design of a cogeneration plant subjected to several constraints is a well established problem, which suggests the use of artificial intelligence (AI, computational techniques that codify and emulate the reasoning patterns of human mind) to automate part of this task.

Since the design process is highly based on knowledge that experts have in a particular domain, the AI techniques known as knowledge-based systems (KBS) are an adequate approach for the cogeneration plant design. One of the most important KBS techniques is the expert system (ES), which has been successfully applied to energy systems design (Akagi et al.,1988; Melli and Sciubba, 1997; Manolas and Efthimeros; 2001; Matelli and Bazzo, 2006).

However, the typical ES approach presents some limitations, especially regarding maintenance of the knowledge-base and learning from previous experiences (Vargas and Raj, 1993). Case-based reasoning (CBR) is a KBS technique that can overcome some of the ES limitations, particularly those mentioned before. Over the last years, CBR has become one of the most attractive IA method, so attractive that in 1991 Marvin Minsk, cited in Wangenheim and Wangenheim (2003), predicted that "*… 20 years from now CBR will be the most important application of Artificial Intelligence*". Basically, CBR solves a new problem by retrieving a solution from a similar situation. More specifically, CBR uses cases previously known so that a new problem is solved based on the assumption that similar problems have similar solutions. The similar solution can be either totally or partially applied to the new problem. It can also be modified according to the requirements of the new problem. The new solution is then reviewed and corrected (if necessary), it also can be stored in the case-base for future use, characterizing the system's learning.

The application of CBR in cogeneration plant design is an original and important contribution of this work, although CBR has been applied to somewhat similar problems like process engineering design (Avramenko and Kraslawski, 2006), synthesis of separation processes (Seuranen et al., 2005) and selection of reactive distillation column (Avramenko et al., 2004). The objective of this article is to discuss some aspects of the CBR approach for cogeneration plant design, as well as presenting a preliminary CBR scheme implemented.

2. CASE-BASED REASONING

In Fig.1 is presented the CBR cycle proposed by Aamodt and Plaza (1994). The authors described the cycle as follows: an initial description of a problem (top of figure) defines a new case. This new case is used to *retrieve* a case from the collection of previous cases. The retrieved case is combined with the new case – through *reuse* – into a solved case, i.e. a proposed solution to the initial problem. Through the *revise* process this solution is tested for success, e.g. by being applied to the real world environment or evaluated by a teacher or expert, and repaired if failed. During *retain*, useful experience is retained for future reuse, and the case base is updated by a new learned case, or by modification of some existing cases.

Nomenclature

A	HRSG heat exchange area (m^2)	$\dot{m}_{ng}$	PM exhaust gases flow (kg/s)
D	Power demand (kW)	$\dot{m}_{ng}$	Natural gas flow (kg/s)
E_d	Daily energy (GJ)	$\dot{m}_{st}$	Steam flow (kg/s)
L	PM partial load (–)	n_{PM}	Number of prime movers
LHV	Nat. gas lower heating value (47 GJ/kg)	*Greeks*	
P_{st}	Saturated steam pressure (MPa)	η_{PM}	PM efficiency (–)
PP	HRSG pinch point (K)	η_{pl}	Overall cog. plant efficiency (–)
Q	HRSG capacity; SB capacity (kW)	η_{SB}	SB efficiency (0.84)
S	Steam demand (kW)	μ	PM utilization factor (–)
T_{rc}	Returning condensate temperature (333.2 K)	*Subscripts*	
T_g	PM exhaust gases temperature (K)	HRSG	Heat recovery steam generator
$T_{st}^{P_{st}}$	Saturation steam temperature at P_{st} (K)	PM	Prime mover
T_{sk}	Stack gases temperature (K)	SB	Natural gas-fired steam boiler
U	Overall heat transfer coefficient (W/m^{2}K)	ev	HRSG evaporator section
W	PM power; Cog. plant available power (kW)	ec	HRSG economizer section
c_{P_g}	PM exhaust gases spec. heat (1.2 kJ/kgK)	max	Maximum
c_{P_w}	Water specific heat (4.2 kJ/kgK)	min	Minimum
$h_{lv}^{P_{st}}$	Water enthalpy of vap. at P_{st} (kJ/kg)		

Since the objective of CBR is to reuse known solutions in the context of the new problem, the choice of the cases in the case-base that can be potentially used to provide an effective solution is a major issue in this AI technique (Wangenheim and Wangenheim 2003). Consequently, a quantitative measure of how much a case is similar to the new problem is required. This measure is known as similarity and in order to be calculated the cases must be properly represented. Typically, a case represents the description of a situation (the problem) and the experience retained (the solution) during its resolution. Thus, a case is an association of two sets of information: one set is the problem description and the other one is its solution (Wangenheim and Wangenheim 2003). In Fig. 2 examples of a case and a case-base are depicted.

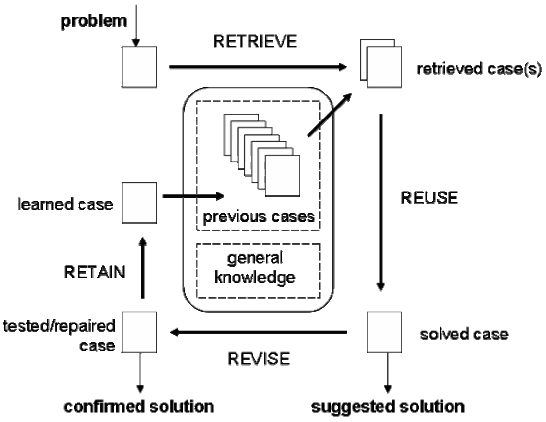
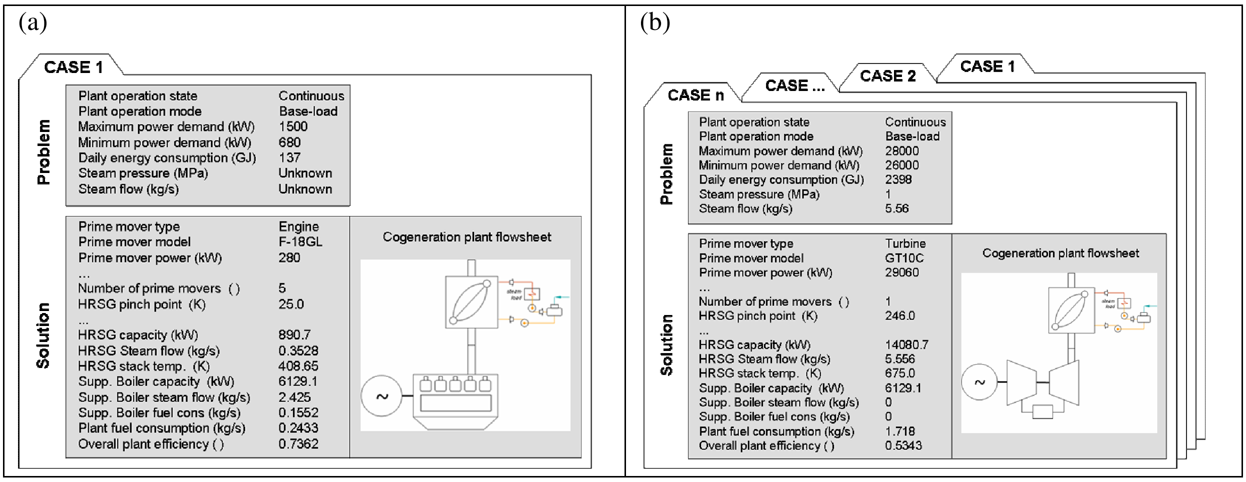


Figure 1. The CBR cycle (adapted from Aamodt and Plaza, 1994).



(a)

Plant operation state	Continuous
Plant operation mode	Base-load
Maximum power demand (kW)	1500
Minimum power demand (kW)	680
Daily energy consumption (GJ)	137
Steam pressure (MPa)	Unknown
Steam flow (kg/s)	Unknown

Prime mover type	Engine
Prime mover model	F-18GL
Prime mover power (kW)	280
...	
Number of prime movers ( )	5
HRSG pinch point (K)	25.0
...	
HRSG capacity (kW)	890.7
HRSG Steam flow (kg/s)	0.3528
HRSG stack temp. (K)	408.65
Supp. Boiler capacity (kW)	6129.1
Supp. Boiler steam flow (kg/s)	2.425
Supp. Boiler fuel cons (kg/s)	0.1552
Plant fuel consumption (kg/s)	0.2433
Overall plant efficiency ( )	0.7362

(b)

Plant operation state	Continuous
Plant operation mode	Base-load
Maximum power demand (kW)	28000
Minimum power demand (kW)	26000
Daily energy consumption (GJ)	2398
Steam pressure (MPa)	1
Steam flow (kg/s)	5.56

Prime mover type	Turbine
Prime mover model	GT10C
Prime mover power (kW)	29060
...	
Number of prime movers ( )	1
HRSG pinch point (K)	246.0
...	
HRSG capacity (kW)	14080.7
HRSG Steam flow (kg/s)	5.556
HRSG stack temp. (K)	675.0
Supp. Boiler capacity (kW)	6129.1
Supp. Boiler steam flow (kg/s)	0
Supp. Boiler fuel cons (kg/s)	0
Plant fuel consumption (kg/s)	1.718
Overall plant efficiency ( )	0.5343

Figure 2. Examples of: a case (a); a case-base (b).

The following definitions are found in the work of Kraslawsky *et al.* (1993). A case is an instance I_i of a database, where i = 1,n is a particular case. Every instance I_i is characterized by X_j attributes, where j = 1,m is a particular attribute. The new problem P is also characterized by X_j attributes, but here j = 1,p and generally m ≠ p. The CBR system must then find a set of cases I_i nearest to P in the sense of the defined metric in the n-dimensional space: the lower the distance between I_i and P, the higher the similarity between them. For a given X_j attribute, the measure of the distance of the new problem P and a case I_i is based on the Minkowski r-metric d:

$$d(P,I_i)_j = \left(\int_{-\infty}^{+\infty} \left| P(X_j) - I_i(X_j) \right|^r dX_j \right)^{\frac{1}{r}} \tag{1}$$

Depending on the r value, well-known distance functions are created, such as Hamming (r = 1), Euclidean (r = 2) or Chebyshev (r = ∞). The Hamming and Euclidean distances are wide-spread in many CBR applications (Wangenheim and Wangenheim 2003; Avramenko and Kraslawski, 2006). However, the distance is an absolute measure of similarity. It is more convenient to normalize it in a range from 0 to 1, where 0 means total dissimilarity and 1 means total similarity. For numeric attributes the linear function of similarity, Eq. (2), is a proper normalized measure of similarity between $P(X_j)$ and $I_i(X_j)$. Note that Eq. (2) is based on the Hamming distance. For attributes that no partial match is allowed, the similarity is either 1, if $P(X_j)$ exactly matches $I_i(X_j)$,or 0 otherwise, as shown in Eq. (3).

$$\text{locsim}\left[P(X_j), I_i(X_j) \right] = 1 - \frac{\left| P(X_j) - I_i(X_j) \right|}{\max(X_j) - \min(X_j)} \tag{2}$$

$$\text{locsim}\left[P(X_j), I_i(X_j) \right] = \begin{cases} 1, \; P(X_j) = I_i(X_j) \\ 0, \; P(X_j) \neq I_i(X_j) \end{cases} \tag{3}$$

Both Eqs. (2) and (3) refers to local similarity, i.e., the similarity between an i-case attribute $I_i(X_j)$ and the same attribute $P(X_j)$ of the problem. In order to calculate the similarity between the cases (known as global similarity) all the local similarities are considered. Generally the attribute have weights: the higher the weight of an attribute, the higher its contribution on the global similarity. In other words, the global similarity is a weighted average of the local similarities, as shown in Eq. (4).

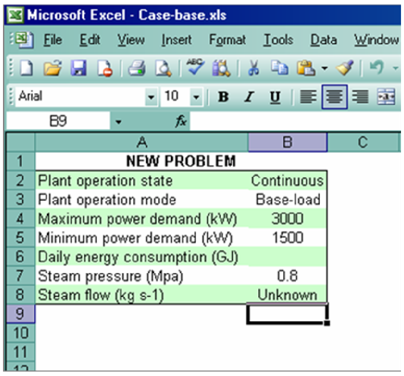
$$\text{sim}(P,I_i) = \frac{\sum_{j=1}^{n} w_j \cdot \text{locsim}\left[P(X_j), I_i(X_j) \right]}{\sum_{j=1}^{n} w_j} \tag{4}$$

The case with the higher value of sim(P,I_i) is the one that is reused to generate a solution. According Watson (1997), in many circumstances this is sufficient to have a solution to the problem. Unfortunately this is not the case in engineering design. The CBR system must adapt the retrieved case to the needs of the problem. Among several adaptation techniques (presented in Watson, 1997), the *parameter adjustment technique* seems to be the most appropriated to the cogeneration plant design problem, because it compares specified parameters of the retrieved case and the problem, applying adaptation rules or formulas directly to the retrieved case in order to generate the final solution. As usual in any KBS methodology, the solution must be validated and, if no correction is required, the solution is stored in the case-base.

3. CBR SCHEME FOR COGENERATION PLANT DESIGN

3.1. Problem presentation and similarity calculation

The previously presented concepts are applied to build a preliminary CBR scheme for cogeneration plant design. The utilities considered are limited to power and saturated steam. Basically, a cogeneration plant that meets such utilities has a prime mover (engine or gas turbine) to produce power and a HRSG to produce steam. HRSG are unfired boilers that use the prime mover exhaust gases to produce steam. They tend to be larger, with more heat exchange surface than a fired boiler with the same capacity. The heat recovery is limited by the temperature of the gases leaving the HRSG stack: the lower this temperature, the higher the heat recovered. However, temperatures lower than 393 K is not recommended in order to avoid formation and condensation of acids in the stack. A supplemental fired boiler is required if the stem demand is higher than the available exhaust gases heat. The CBR scheme is implemented in a data-sheet and is divided in three parts. In the first part the user informs the cogeneration plant requirements (Fig. 3). These requirements are the attributes that are compared between the problem and the cases. Here one can note one of the main characteristic of KBS techniques: the ability to deal with incomplete or unknown data. This is desirable because the designer of a cogeneration plant faces quite often this situation.

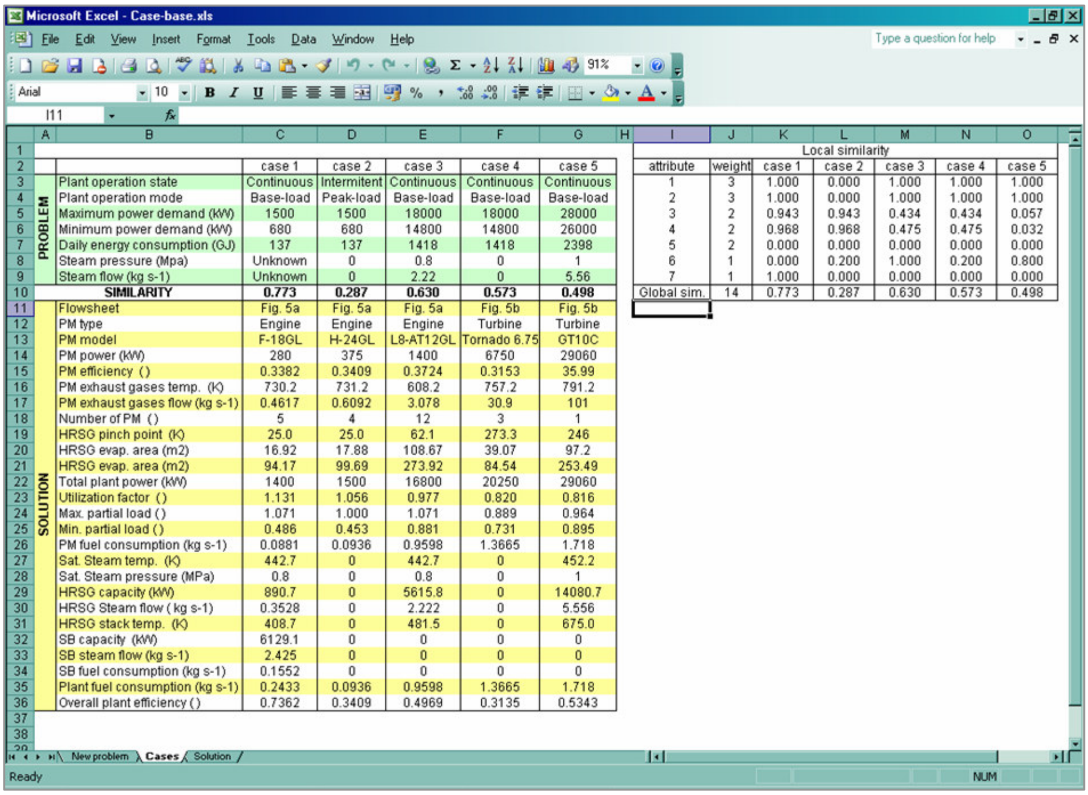


	A	B	C
1	NEW PROBLEM		
2	Plant operation state	Continuous	
3	Plant operation mode	Base-load	
4	Maximum power demand (kW)	3000	
5	Minimum power demand (kW)	1500	
6	Daily energy consumption (GJ)		
7	Steam pressure (Mpa)	0.8	
8	Steam flow (kg s-1)	Unknown	
9			
10			
11			

Fig. 3. Design requirements.

In the second part of the CBR scheme the problem attributes are compared to the attributes of five cases (Fig. 3), all of them generated by the ES developed by the authors and reported in Matelli and Bazzo (2006). It is an obviously small case-base, and this can lead to an inappropriate solution if the cases are not similar enough to the problem (Avramenko and Kraslawski, 2006). However, the aforementioned case-base is sufficient for the purposes of this work.

Note that the plant scheme is part of the solution for every case (see first line of the solution part in Fig. 4). The schemes are depicted in Fig. 5. As shown in Fig. 4, one can see that the most similar case is the case 1, presenting a global similarity equal to 0.773. The most dissimilar case is case 2, which presents a global similarity equal to 0.287. The local similarity of the attributes 1 and 2 are calculated according Eq. (3). All others local similarities are calculated through Eq. (2). So case 1 is the case retrieved to generate the problem solution in the third part of the CBR scheme (Fig. 6). It is interesting to note that the steam flow is unknown in both the problem and the retrieved case. However the CBR is able to size the steam generating subsystem based on the expert knowledge that steam flow in the range from 0.9722 to 2.778 kg/s is adequate for most of applications.



		case 1	case 2	case 3	case 4	case 5
PROBLEM	Plant operation state	Continuous	Intermitent	Continuous	Continuous	Continuous
	Plant operation mode	Base-load	Peak-load	Base-load	Base-load	Base-load
	Maximum power demand (kW)	1500	1500	18000	18000	28000
	Minimum power demand (kW)	680	680	14800	14800	26000
	Daily energy consumption (GJ)	137	137	1418	1418	2398
	Steam pressure (Mpa)	Unknown	0	0.8	0	1
	Steam flow (kg s-1)	Unknown	0	2.22	0	5.56
SIMILARITY		**0.773**	**0.287**	**0.630**	**0.573**	**0.498**
SOLUTION	Flowsheet	Fig. 5a	Fig. 5a	Fig. 5a	Fig. 5b	Fig. 5b
	PM type	Engine	Engine	Engine	Turbine	Turbine
	PM model	F-18GL	H-24GL	L8-AT12GL	Tornado 6.75	GT10C
	PM power (kW)	280	375	1400	6750	29060
	PM efficiency ()	0.3382	0.3409	0.3724	0.3153	35.99
	PM exhaust gases temp. (K)	730.2	731.2	608.2	757.2	791.2
	PM exhaust gases flow (kg s-1)	0.4617	0.6092	3.078	30.9	101
	Number of PM ()	5	4	12	3	1
	HRSG pinch point (K)	25.0	25.0	62.1	273.3	246
	HRSG evap. area (m2)	16.92	17.88	108.67	39.07	97.2
	HRSG evap. area (m2)	94.17	99.69	273.92	84.54	253.49
	Total plant power (kW)	1400	1500	16800	20250	29060
	Utilization factor ()	1.131	1.056	0.977	0.820	0.816
	Max. partial load ()	1.071	1.000	1.071	0.889	0.964
	Min. partial load ()	0.486	0.453	0.881	0.731	0.895
	PM fuel consumption (kg s-1)	0.0881	0.0936	0.9598	1.3665	1.718
	Sat. Steam temp. (K)	442.7	0	442.7	0	452.2
	Sat. Steam pressure (MPa)	0.8	0	0.8	0	1
	HRSG capacity (kW)	890.7	0	5615.8	0	14080.7
	HRSG Steam flow (kg s-1)	0.3528	0	2.222	0	5.556
	HRSG stack temp. (K)	408.7	0	481.5	0	675.0
	SB capacity (kW)	6129.1	0	0	0	0
	SB steam flow (kg s-1)	2.425	0	0	0	0
	SB fuel consumption (kg s-1)	0.1552	0	0	0	0
	Plant fuel consumption (kg s-1)	0.2433	0.0936	0.9598	1.3665	1.718
	Overall plant efficiency ()	0.7362	0.3409	0.4969	0.3135	0.5343

Local similarity						
attribute	weight	case 1	case 2	case 3	case 4	case 5
1	3	1.000	0.000	1.000	1.000	1.000
2	3	1.000	0.000	1.000	1.000	1.000
3	2	0.943	0.943	0.434	0.434	0.057
4	2	0.968	0.968	0.475	0.475	0.032
5	2	0.000	0.000	0.000	0.000	0.000
6	1	0.000	0.200	1.000	0.200	0.800
7	1	1.000	0.000	0.000	0.000	0.000
Global sim.	14	0.773	0.287	0.630	0.573	0.498

Fig. 4. Case-base and similarity calculation.

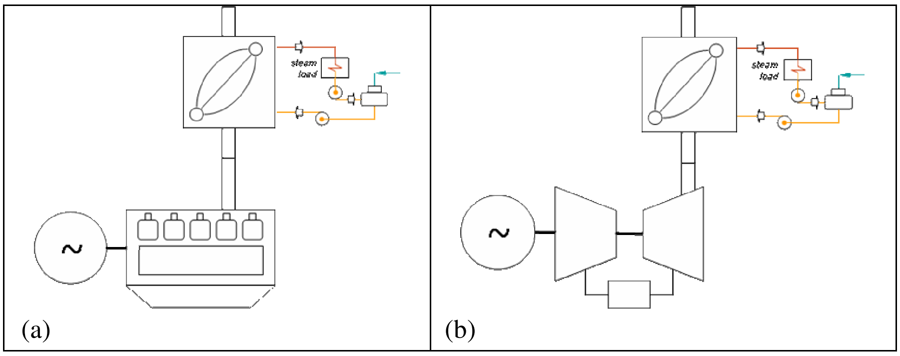


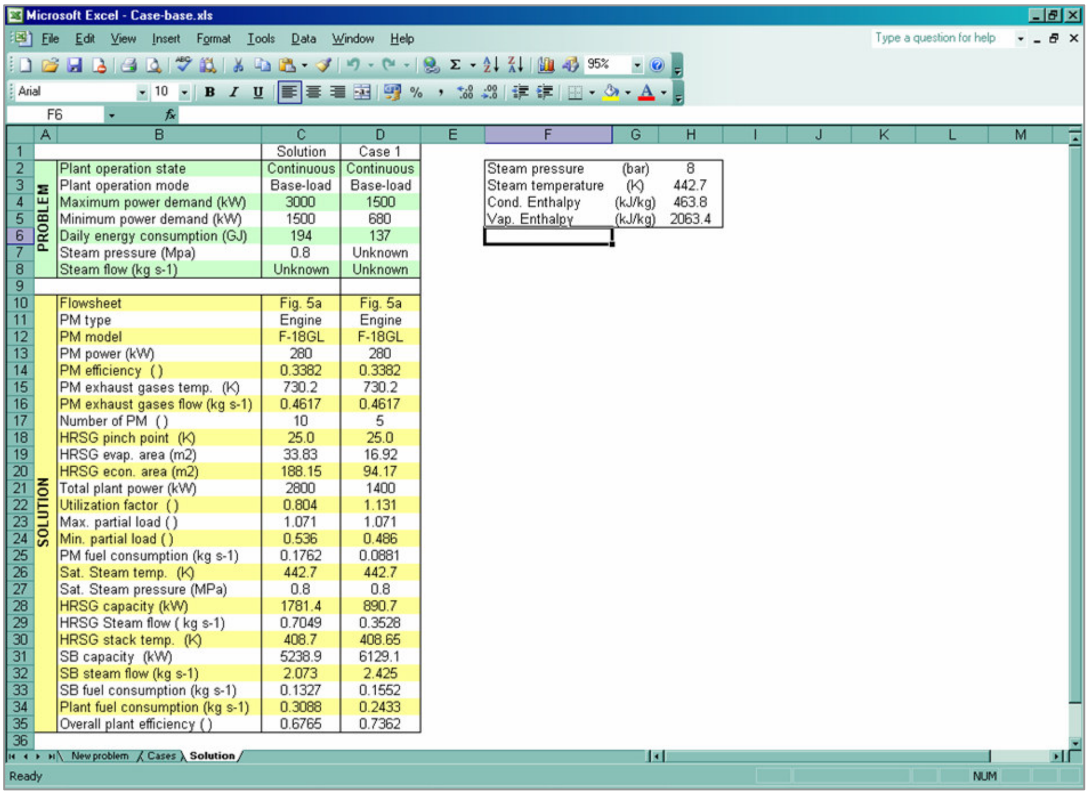
Figure 5. Plant schemes based on engine (a) and turbine (b).

3.2. Adaptation of the retrieved solution

The third part of the process is related to the adaptation. Basically adaptation requires the recalculation of the number of prime movers, which allows determining the amount of exhaust gases heat available for recovering. Consequently all the design parameters of a HRSG are calculated, indicating if a supplemental boiler is necessary. This is in accordance with the *parameter adjustment adaptation technique* previously described; where adaptation rules and/or formulas are directly applied to the retrieved case in order to generate the final solution. These rules and formulas are used in the ES developed by the authors and presented in Matelli and Bazzo (2006) and can be used in the CBR adaptation part. The detailed description of such procedure is presented as follows.

According to the expert knowledge, the prime mover should be sized to meet 90% of the maximum power demand, because in most cases the power demand is greater than this value only for short periods of time, and the movers generally can operate overloaded for a moment. Thus the number of the mover suggested by the retrieved case is given by Eq. (5), so that the cogeneration plant available power is given by Eq. (6):

$$n_{PM} = \text{greater integer}\left(\frac{0.9D_{max}}{W_{PM}}\right) \tag{5}$$



		Solution	Case 1
PROBLEM	Plant operation state	Continuous	Continuous
	Plant operation mode	Base-load	Base-load
	Maximum power demand (kW)	3000	1500
	Minimum power demand (kW)	1500	680
	Daily energy consumption (GJ)	194	137
	Steam pressure (Mpa)	0.8	Unknown
	Steam flow (kg s-1)	Unknown	Unknown
SOLUTION	Flowsheet	Fig. 5a	Fig. 5a
	PM type	Engine	Engine
	PM model	F-18GL	F-18GL
	PM power (kW)	280	280
	PM efficiency ( )	0.3382	0.3382
	PM exhaust gases temp. (K)	730.2	730.2
	PM exhaust gases flow (kg s-1)	0.4617	0.4617
	Number of PM ( )	10	5
	HRSG pinch point (K)	25.0	25.0
	HRSG evap. area (m2)	33.83	16.92
	HRSG econ. area (m2)	188.15	94.17
	Total plant power (kW)	2800	1400
	Utilization factor ( )	0.804	1.131
	Max. partial load ( )	1.071	1.071
	Min. partial load ( )	0.536	0.486
	PM fuel consumption (kg s-1)	0.1762	0.0881
	Sat. Steam temp. (K)	442.7	442.7
	Sat. Steam pressure (MPa)	0.8	0.8
	HRSG capacity (kW)	1781.4	890.7
	HRSG Steam flow (kg s-1)	0.7049	0.3528
	HRSG stack temp. (K)	408.7	408.65
	SB capacity (kW)	5238.9	6129.1
	SB steam flow (kg s-1)	2.073	2.425
	SB fuel consumption (kg s-1)	0.1327	0.1552
	Plant fuel consumption (kg s-1)	0.3088	0.2433
	Overall plant efficiency ( )	0.6765	0.7362

Steam pressure	(bar)	8
Steam temperature	(K)	442.7
Cond. Enthalpy	(kJ/kg)	463.8
Vap. Enthalpy	(kJ/kg)	2063.4

Figure 6. Adaptation of the case retrieved and final solution.

$$W_{plant} = n_{PM} W_{PM} \tag{6}$$

The prime mover utilization factor is defined as the ratio between the daily energy (in GJ) and the energy that can be delivered by the cogeneration plant during 24 h (also in GJ), as seen in Eq. (7).

$$\mu = \frac{E_d}{0.0864 W_{plant}} \tag{7}$$

The prime mover's maximum and minimum partial load operation are calculated by Eqs. (8) and (9), respectively.

$$L_{max} = \frac{D_{max}}{W_{plant}} \tag{8}$$

$$L_{min} = \frac{D_{min}}{W_{plant}} \tag{9}$$

Finally, the fuel consumption of the movers is given by Eq. (10):

$$\dot{m}_{ng,PM} = \frac{W_{plant}}{\eta_{PM} LHV} \tag{10}$$

Regarding the steam demand, the pinch point (Eq. 11) and the stack gases temperature (Eq. 12) are the key parameter in the HRSG sizing. They are calculated considering the heat recovery from the prime mover exhaust gases.

$$PP = T_g - T_{st}^{P_{st}} - \frac{\dot{m}_{st} h_{lv}^{P_{st}}}{n_{PM} \dot{m}_g c_{P,g}} \quad (11)$$

$$T_{sk} = T_g - \frac{\dot{m}_{st}}{n_{PM} \dot{m}_g c_{P,g}} \left[h_{lv}^{P_{st}} - c_{P,w} \left(T_{st}^{P_{st}} - T_{rc} \right) \right] \quad (12)$$

Once defined the HRSG steam mass flow, its capacity is given by Eq. (13), and the HRSG heat exchange surfaces are calculated according Eqs (14) and (15) for the evaporator section (U = 0.4 kW m^{-2} K^{-1}) and economizer section (U = 0.038 kW m^{-2} K^{-1}) [19], respectively.

$$Q_{HRSG} = \dot{m}_{st,HRSG} \left[h_{lv}^{P_{st}} + c_{P,w} \left(T_{st}^{P_{st}} - T_{rc} \right) \right] \quad (13)$$

$$A_{ev} = \frac{n_{PM} \dot{m}_g c_{P,g} \left[T_g - \left(T_{st}^{P_{st}} + PP \right) \right]}{U \left[\left(T_g - T_{st}^{P_{st}} - PP \right) \right]} \ln \left(\frac{T_g - T_{st}^{P_{st}}}{PP} \right) \quad (14)$$

$$A_{ec} = \frac{n_{PM} \dot{m}_g c_{P,g} \left[\left(T_{st}^{P_{st}} + PP \right) - T_{sk} \right]}{U \left[PP - \left(T_{sk} - T_{rc} \right) \right]} \ln \left(\frac{PP}{T_{sk} - T_{rc}} \right) \quad (15)$$

The natural gas-fired boiler, if required, has its capacity and steam mass flow calculated by Eq. (16) and (17), respectively. Its fuel consumption is calculated by Eq. (18).

$$Q_{SB} = S - Q_{HRSG} \quad (16)$$

$$\dot{m}_{st,SB} = \dot{m}_{st} - \dot{m}_{st,HRSG} \quad (17)$$

$$\dot{m}_{ng,SB} = \frac{Q_{SB}}{\eta_{SB} LHV} \quad (18)$$

Finally, the overall cogeneration plant efficiency is given by:

$$\eta_{pl} = \frac{W_{plant} + Q_{HRSG} + Q_{SB}}{\left(\dot{m}_{ng,PM} + \dot{m}_{ng,SB} \right) LHV} \quad (19)$$

The CBR cycle rarely occurs without human intervention. The case revision and adaptation is often undertaken by the user (Watson, 1997). In order to validate the adapted solution, the cogeneration plant designer must keep the following considerations in mind:

i. The utilization factor (Eq. 7) is a key parameter when selecting a prime mover: the higher the utilization factor, the lower the operation and installation costs;
ii. The maximum partial load operation (Eq. 8) of the prime mover should not exceed 1.1, because most of the engines and turbines commercially available do not operate more about such rate. The minimum partial load operation (Eq. 9) should not be lower than 0.5 for engines, because the efficiency decreases and the operation costs will be very high. For turbines, the minimum partial load should not be lower than 0.7, for two reasons: first, because the efficiency would decrease significantly; second, because turbines have in general slow load response;
iii. Eventually the prime movers exhaust gases heat is not enough to produce the required steam demand. This is the case when one of the following situations occurs:

   a. the pinch point is lower than 15 K, which implies in high heat exchange surface and high initial cost (note that a pinch point lower than zero is a violation of the second law of thermodynamics).

So the pinch point is set to 25 K and Eq. (11) is used to calculate the HRSG steam mass flow $\dot{m}_{st,HRSG}$. Equation (12) is then evaluated by $\dot{m}_{st} = \dot{m}_{st,HRSG}$;

b. the stack gases temperature is lower than 393.2 K, which is not recommended in order to avoid formation and condensation of acids in the stack. So the stack gases temperature is set to 393.2 K. Eq. (12) is used to calculate the HRSG steam mass flow $\dot{m}_{st,HRSG}$. Equation (11) is then evaluated by $\dot{m}_{st} = \dot{m}_{st,HRSG}$;

Since the solution is validated it can be stored as the sixth case of the CBR scheme case-base, being available for future use. The solution of the proposed problem represented a new experience to the system, and by storing this experience it can be said that the system has learned from its previous experience.

5. CONCLUSION

In this paper the design problem of natural gas cogeneration systems is modeled through AI techniques known as knowledge-based systems (KBS). Expert systems (ES) and case-based reasoning (CBR) are two of the most important KBS techniques. In this work, the basic concepts of the CBR technique and a preliminary CBR scheme for cogeneration plant design are presented. The CBR scheme is able to find a solution from previous cases through the similarity calculation, but the adaptation and case storing is undertaken by the user.

6. ACKNOWLEDGEMENTS

To the National Petroleum Agency, through the Mecpetro/UFSC: Program of Humam Resources in Mechanical Engineering for Petroleum and Gas, Federal University of Santa Catarina, for the financial support;

To Guilherme José Binelli, M. Sc., for sharing with us his wide experience in cogeneration.

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PROJETO DE PLANTAS DE COGERAÇÃO ATRAVÉS DE RACIOCÍNIO BASEADO EM CASOS

O artigo aborda o problema de se projetar sistemas de cogeração a gás natural. Apesar da sua complexidade, tal problema, sujeito a várias restrições, é adequadamente resolvido por seres humanos, o que sugere o uso de inteligência artificial (IA). Além disso, o projeto é uma atividade fortemente baseada no conhecimento que especialistas possuem sobre um determinado domínio. Assim, técnicas de IA conhecidas por sistemas baseados em conhecimento (SBC) são adequadas para projeto de plantas de cogeração. Raciocínio baseado em casos (RBC) é uma das mais importantes técnicas de SBC da atualidade. No presente trabalho, os conceitos básicos do RBC e um esquema preliminar de uma aplicação de RBC para projeto de plantas de cogeração são apresentados.

Cogeração, Projeto, Gás natural, Raciocínio baseado em casos.