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NUCLEAR POWER PLANTS FOR PEAK LOADS IN POWER SYSTEMS, USING THE HYDROGEN AS ENERGY AGENT

MIRCEA CÂRDU¹, MALVINA BAICA²

Key words: Hydrogen as energy agent, Power systems load, Peak loads.

In this paper are analysed the technical possibilities of Nuclear Power Plants to participate at in a peak load period of a power system by producing hydrogen in basic load conditions and utilization of hydrogen as fuel to deliver additional electrical energy.

1. INTRODUCTION

Among the many great provocations that the actual civilization has to face, two are which most interest our energy specialists.

On the one hand, there is about the gloomy perspective, relatively near, of the exhaustion of conventional energy resources based on conventional fossil fuels that presently have an essential weight in producing electrical and thermal energy as well as in transportation.

On the other hand, with as well as critical consequences for the future of mankind, it is proved to be the rapid increase of noxious gas emissions and greenhouse gases resulting from fuels combustion.

It is known that the nuclear and renewable energy represents two essential way to solve the most important two mentioned problems.

Thus, even presently, countries with a high technological and economical level, as France and Belgium, have highly developed nuclear power. In its turn, Romania, in expressing its wish to be integrated into EU, is also developing its nuclear power. Presently, the energy produced by first of 700 MWe Cernavoda Nuclear Power Plant (NPP) represents about 10% of the total electrical energy produced. After the year 2005, when the second nuclear unit of 700 MWe will start to operate, this proportion will become about 20%. It will continue to increase up

¹ SC HERBING SRL Bucharest

² University of Wisconsin, Whitewater, WI, USA

to 25% in the period 2010–2050, when the third power unit in NPP Cernavoda will start to operate.

Practically, the problem of active material (fuel) exhaustion for Nuclear Reactors (NR) need to be discussed for some centuries. The fact that the primary nuclear power resources are practically unexhausted, and the NPPs do not emit noxious or greenhouse gases into the atmosphere constitute the principal advantages for these power plants. The rise of NPPs importance is determined from the fact that, generally, the highest energy consumption is encountered in those geographical zones that do not dispose of rich conventional fuels resources.

Besides the many advantages regarding the big reserve of nuclear fuel and the environmental protection these NPPs have also the following principal disadvantages:

- Cannot be placed in populated zones, thus in the vicinity of big cities, in tourist zones, or zones with a high seismic level. In these conditions, in very few cases, NPPs can be used as cogeneration plants;

- Are not adequate to operate with a variable load, they practically operate permanently at nominal load;

- Require large quantity of cooling water, thus usually they must be located on the sea shores or in the vicinity of big rivers;

- Depositing the radioactive waste resulting from the NPPs operation, represent a problem difficult to solve (see Yucca Mountain, Nevada project from USA [1]).

The first two disadvantages mentioned above, can be compensated by introducing an energy agent between the big electrical energy producer NPP and local electrical producers, capable to function at a variable load or local electrical and thermal (cogeneration) producers. Such agent, the best from the point of view of noxious and greenhouses gases emissions is hydrogen. The hydrogen has a great advantage that it can be used as fuel in transportation, and we cannot forget that 32% of the primary energy used in the world today (for energy, industry, transportation etc) is meant for transportation [2, 3].

2. NPP AS AN ENERGY SOURCE TO PRODUCE HYDROGEN

One principal and non-pollutant electrical energy source that could be used to produce hydrogen (H) in large quantities by electrolysis is from NPPs. This is important since in the future it is foreseen as a special development of nuclear power.

There is another reason that NPPs are best suited to be used as an energy source to produce H. This reason is connected with the fact that, by their nature, NPPs have to operate with a very constant load, equal, evidently, as much as

possible, with the economical load (in NPPs case, nominal load). On the other hand, the Power Systems (PSs) in which NPPs are included, register variable electrical energy demands. This will determine that the annual load curve which characterize PS, to be irregular, and in the Romanian case, having maximum values during the winter and some increase in the value during the summer. High electrical energy consumption in winter (especially from November through January) is explained by the use of the heating systems operating at a maximum capacity, and increased demand regarding common transportation, public and domestic lighting, as well as the activities connected with the commercial character during the holiday season.

The electrical energy consumption increase during the months of July and August is explained by the maximum capacity operation of agricultural irrigation systems and air conditioning installations. In Romania, this consumption will register an important increase because a large development of such systems and installations is foreseen.

The annual load curve of Romanian PS for the year 2001 is represented in Fig. 1 [4].

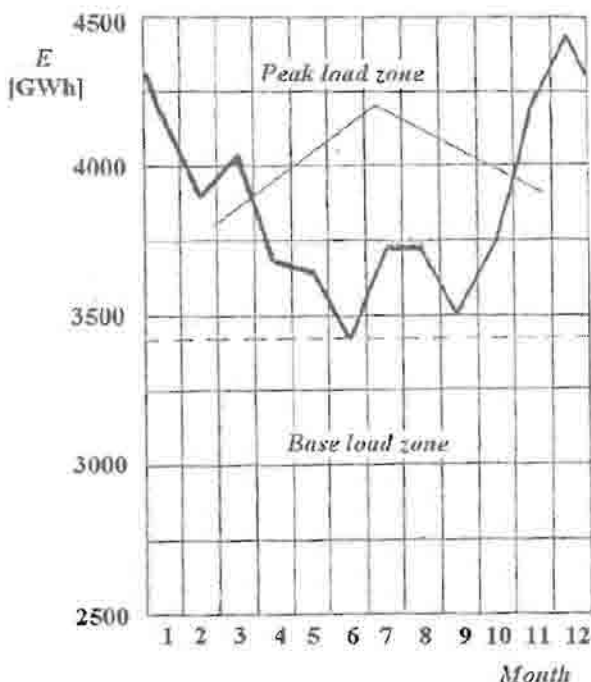


Fig. 1 – Electric energy load curve in the Romanian Power System of the year 2001.

Of course, in detail, the load curve is not as continuous as in Fig.1. At each day level, the daily load curve, this time registers maximum values at 9:00 am and 5:00 pm.

The Power Plants (PPs), respectively Power Units (PUs) adequate to function with a constant power provide energy in the basic running load zone. If we refer to the curve of Fig.1, the base running load correspond to a power of about 3500 MW. This load was provided out of NPP Cernavoda (700 MW), of base Hydro Power Plants (HPPs), among the most important are HPPs on the Danube River (Iron Gates I and Iron Gates II) and of Thermo Power Plants (TPPs) of high power. In these PPs the electrical energy is produced at a minimum price. As the need for the electrical energy rises to the maximum values of the load curve, called top values, in PS are connected PUs which from technical point of view it is not necessary to operate permanently. Of course, that such PUs are successively introduced in PS, in function of increasing order in price of electrical energy they produce.

There are PSs where in most cases the electrical energy is produced in TPPs and/or NPPs properly equipped to function at a constant load. For these cases, to cover the peak value of load curve becomes a difficult problem. That is why, to pass from a peak zone to the basic zone of load curve, it is necessary a drastic reduction or to even shut off some PUs of TPPs, when these have an important participation to the energy delivery in the load curve limits of PS. In NPPs case, the problem of an important power decrease compared with the nominal value is not considered, since this would be totally uneconomical and is not recommended from the technical point of view. For these situations is suitable a NPP with operation of a constant power, deliver in PS of needed energy conform load curve and electrical energy surplus to be used in producing H by electrolysis.

The efficiency of producing H by electrolysis has values in the range of (60–80)% [2]. Considering that the electrical energy efficiency produced in NPPs is of (34–36)%, and the electrical consumption for its own services is about 8%, it follow that the total efficiency of H producing by electrolysis, starting from nuclear energy, is (19–20)%.

At present, great attention is given in producing H by applying some technological processes where it is planned to obtain total (global) efficiency values higher than 50 % [5].

In the following chapter, we will analyse the technical aspects of some different NPPs where the electrical energy produced is used to produce H by electrolysis. Hydrogen, in its turn, is used to produce superheated steam, completely separated from the Nuclear Plant for Steam Production (NPSP). The power installation includes as much a saturated (from NPSP) steam turbine as turbine with superheated steam (Fig. 2).

Since, the superheated steam is obtained by H combustion, we will call these respective installations "Nuclear Power Plants with steam superheated by Hydrogen Combustion (NPPHC)".

As a rule, NPPHC installations could be used to ensure the supplemental electrical energy supply for the "peak" zone of the load curve of the PS (see Fig.1). Thus, with the help of electrical energy obtained from nuclear energy, H can be produced and, by its combustion, the supplemental electric energy is produced, in order to be delivered in PS when this will require it.

In what follows, we will give the mathematical models that we elaborated on for representation of these energetic processes that have their place in such installations. Also, we will analyse these respective installations on the basis of some calculation effectuated for concrete examples.

3. NPPs WITH SUPERHEATED STEAM BY HYDROGEN COMBUSTION (NPPHC)

We will analyse the case of some NPPHC equipped with Nuclear Reactors (NRs) CANDU type from PHWR (Pressurized Heavy Water Reactor) category, similar with that of PU No.1 of Cernavoda NPP. This NR type is moderated and cooled with heavy water. The thermal power of PU is $P_{tm}=2062$ MWt, and turbo generator group power (at the electric generator terminals) is $P_{en}=706.5$ MW [5].

The steam (saturated) at the turbine (type N1C700) inlet has a pressure of 45.5 bar. After expansion in the High Pressure (HP) turbine unit, the steam is superheated (after the humidity is retained in a humidity separator) and introduced in the Low Pressure (LP) turbine units. Turbine with speed of 1500 rpm have a unit of HP and three units of LP, having inlet parameters of 10.48 bar; 236.8°C. The pressure in the turbine condenser is of 0.043 bar (the cooling water temperature is of 15 °C). The thermal efficiency of turbine installation is: $\eta_{tu} = 706.5/2062 = 0.34$.

We will further analyse two power installations that are using as a primary thermal energy producer a NPSP of PU with $P_t=2062$ MWt of NPP Cernavoda. The first type, NPPHC-A installation, in its turn, could be of two types (A1 and A2), in function of the procedure how the produced electrical energy in generator 5 (see Fig.2) of installation (N) is used. For type A1 the electrical energy delivered by generator 5 during of its entire operation time is exclusively used to produce H in electrolyser 6 of installation (C) – line (a). For type A2 the electrical energy delivered by generator 5 is directed to the electrolyser 6 only for some part of its operation time, to produce H. The rest of time this piled up H is used in installation (C) to produce electrical energy for PS, and also the electrical energy produced in installation (N) is intended to PS – line (b).

In case A1 the power provision for PS in peak load period is only of installation (C), and for case A2, in the respective period, this power provision for PS is that one cumulative of both installations (N) and (C).

3.1. NPPHC-A1

The simplified thermal diagram of NPPHC-A is represented in Fig.2.

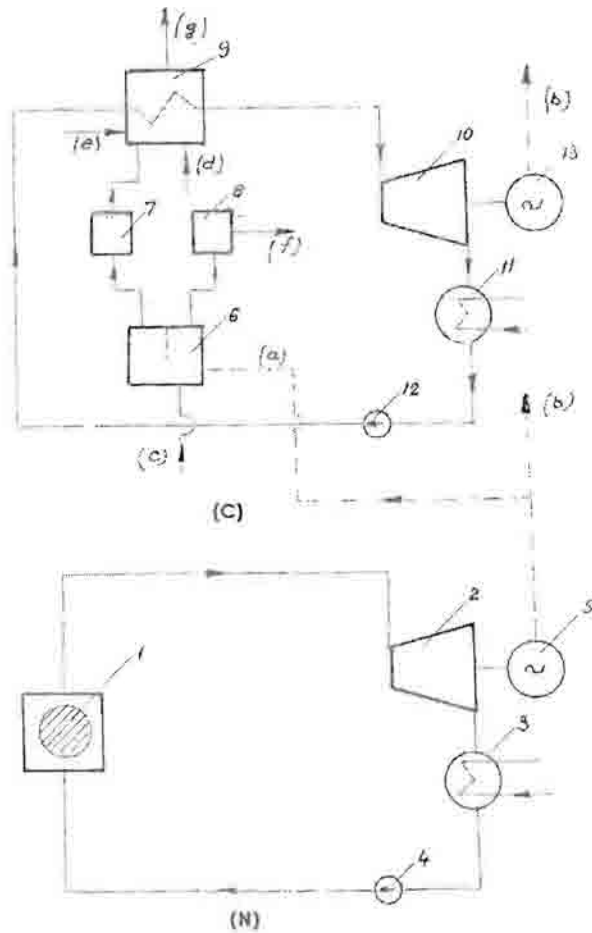


Fig. 2 – The simplified thermal diagram of NPPHC-A: (N)–Nuclear installation; 1–Nuclear Plant for Steam Production (NPSP); 2–steam turbine; 3–(steam) condenser; 4–feed water pump; 5–electrical generator; (C)–Conventional installation; 6–electrolyser; 7–Hydrogen (H) tank; 8–oxygen tank; 9–(steam) boiler; 10–steam turbine; 11–(steam) condenser; 12–feed water pump; 13–electrical generator; (a)–electrical connection between (N) and (C); (b)–electric current to user; (c)–water for electrolysis; (d)–air (or H) for combustion; (e)–air for tempering; (f)–O for third using; (g)–flue gases.

The saturated steam turbine N1C700 is represented at the bottom portion of this figure (N-nuclear).

This installation is mainly composed on NPSP-pos.1, steam turbine 2, condenser 3, feed water pump 4 and electrical generator 5. This generator produced electrical energy that, in its turn, is used to produce H by electrolysis.

The installation represented in the top portion of Fig.2 is a conventional power installation (C) with superheated steam, combined with an installation that produced H by electrolysis.

Theoretically, the only connection between installations (N) and (C) is one of electrical nature, represented in Fig. 2 by interrupted line (a). Practically, such a connection is more complex as it must also include an alternating current rectifying system (ac-alternating current) of the electricity produced by generator 5 in direct current (dc-direct current) needed in the electrolysis process.

Mainly, the conventional installation (C) is composed of electrolyser 6, H tank 7, oxygen tank 8, steam boiler 9, steam turbine 10, steam condenser 11, feed water pump 12 and electrical generator 13. In electrolyser 6, water is introduced and H is produced, which is temporarily stored in tank 7 and oxygen is also temporarily stored in tank 8. H, used as fuel, is then introduced and burned in boiler 9. The oxygen from tank 8 can also be utilised as carrier in the boiler 9 (d).When oxygen can be used in other purposes (f) for some advantageous economical conditions, in the boiler 9 will be introduced air from atmosphere. When in H combustion, the only oxygen resulting from electrolysis in 6 is used, in the boiler 9 is produced a stoichiometric combustion and the temperature could be very high.

In order to temperate the flue gases of boiler 9 stack, even in this case, it could be necessary to introduce atmospheric air (e) – tempering fluid – in boiler 9. From boiler these flue gases are removed in stack (g). In order to simplify Fig. 2, in diagrams (N) and (C) we did not represent many components of the corresponding installations, as could be the regenerative preheating systems, condensation pumps etc.

For the analysis that we further intend to make, we will consider that the installation (C) of Fig.2 is that one of F1C330 steam turbine made in Romania [6]. This turbine has a power of 330 MW (at the electrical generator terminals). The steam pressure at the inlet of this turbine is of 182.4 bar and its temperature is of 535 °C [7].

After its expansion in the turbine High Pressure (HP) unit, the steam is superheated and introduced in its Intermediate Pressure (IP) unit, having as parameters 43.7 bar, 435 °C. The turbine with a speed of 3000 rpm has one HP unit, one IP unit and two Low Pressure (LP) units. The pressure in the condenser is of 0.037 bar. The specific heat consumption is of 8 000 kJ/kWh and thus its thermal efficiency is $\eta_{tc} = 0.45$.

In what follows, we will calculate the time duration in a year (Fig. 1) in which installation (C) can operate in peak running, using as fuel (in boiler 9) the H produced as a result of installation (N) operation during the entire period of the corresponding year, considering, of course, the installation available capability.

We will also calculate energetic efficiency of a complex installation as represented in Fig.2. In order to perform these calculations, we will accept values for some elements that occur in the respective calculations, such as:

- the internal energetic consumption coefficient of NPP Cernavoda $\xi = 0.08$ [8];
- installed power utilization factor for NPP Cernavoda $\nu = 0.87$ [8];
- the efficiency to produce H by electrolysis $\varphi = 0.8$ (shown previously);
- boiler (9) efficiency $\eta_b = 0.92$ [9].

In version A1 case, to calculate our proposed elements, we will use the following computing relations, referring to an one year operation:

Electrical energy furnished by installation (N) and consumed to produce H in electrolyser 6 of installation (C), is given by relation

$$E_{chl} = (1 - \xi/\xi) P_{en} \nu \tau, \quad (6)$$

where $P_{en} = 706,500$ kW, as we mentioned before, and τ is the total time duration (in seconds) of a calendar year, thus $\tau = 365 \times 24 \times 3600 = 3.1536 \times 10^7$ s (respectively 8 760 h). H volume produced as a result of using E_{chl} in electrolysis is:

$$V_{hl} = E_{chl} \zeta / Q_{ih}, \quad (7)$$

where Q_{ih} [kJ/Nm³] is the low caloric power of H.

The energy contained in the steam produced in boiler 9 by burning a volume V_{hl} of H is:

$$E_{phl} = \eta_b V_{hl} Q_{ih}, \quad (8)$$

and, on the other hand, we have:

$$E_{pld} = P_{sc} \kappa_1 \tau / \eta_{loc}, \quad (9)$$

where P_{ec} [kW] is the electrical power of installation (C), κ_1 is the temporal operation coefficient of turbine 10 in peak running, and η_{cc} is the thermal efficiency of installation (C). Making equal the right terms of both equalities in relations (8) and (9), considering relations (6) and (7) and denoting $\pi = P_{en}/P_{ec}$ we obtain relation:

$$\kappa_1 = \eta_b \eta_{ic} \zeta (1 - \xi) \nu \pi. \quad (10)$$

This relation shows that installation (C) can operate in peak running a time duration in a year τ_{p1} (resulted from $\kappa_1 = \tau_{p1}/\tau$) with so much larger as larger are η_b , η_{ic} , ζ , v and π , respectively as much smaller is ξ .

Introducing in (10) the above mentioned values, we obtain $\kappa_1 = 0.567$. This means that, if we express the time in hours, we will have $v\tau = 0.87 \times 8760 = 7621$ hours and respectively $\tau_{p1} = 0.567 \times 8760 = 4967$ hours. In other words, if in a years time an installation (N) of Fig.2 with a power of 706.5 MW continuously operate for 7621 hours time, by combustion of H produced using the respective electrical energy, the installation (C) of 330 MW could operate 4967 hours time, which means about seven months from the total of twelve months. Since installations (N) and (C) operate in different time duration, the energetic efficiency cannot be represented by the ratio between these two powers (see $\eta_m = P_{en}/P_m$), but it results from the ratio between two energies (powers in time).

The energetic efficiency (ε_1) of analysed type system could be represented by the ratio between electric energy produced by installation (C) in time $\kappa_1\tau$ (denoted by E_{el}) and thermal energy delivered by NPSP of installation (N) in time ($v\tau$) for H production (denoted by E_{h1}).

Since, to simplify, we consider that, in time, $P_{ec} = ct$ and $P_m = ct$, we have:

$$\varepsilon_1 = P_{ec} \kappa \tau / P_m v \tau. \quad (11)$$

Having $P_m = P_{en}/\eta_m$, relation (11) becomes:

$$\varepsilon_1 = \kappa_1 \eta_m / \pi v, \quad (12)$$

or, considering relation (10), we will have:

$$\varepsilon_1 = \eta_b \eta_m \eta_{ic} \zeta (1 - \xi). \quad (13)$$

For our case $\varepsilon_1 = 0.103$.

This means that with the help of installation (N) of 706.5 MW that operates in a base running for 7621 hours with a thermal efficiency of $\eta_m = 0.34$, it can be obtained an operation of installation (C) of 330 MW in a peak running for 4967 hours ($\kappa_1 = 0.567$). This energy transfer from base to peak running has in consequence an energy efficiency reduction from $\eta_m = 0.34$ (efficiency) to $\varepsilon_1 = 0.103$ (global efficiency).

3.2. NPPHC-A2

We recall that in A2 case the electrical energy resulted from generator 5 of installation (N) is conducted to electrolyser 6, line (a), only in the time period $(v - \kappa_2)\tau$. The rest of time ($\kappa_2\tau$) this energy is conducted to PS, together with the electrical energy resulted from generator 13 of installation (C).

Applying the same logic as in NPPHC-A1 case we obtain $\kappa_2 = 0.343$, which related to one year duration (12 months), this means about four months.

The global energetic efficiency in this case is $\varepsilon_2 = 0.324$.

3.3. NPPHC-B

We have analysed also a second thermal diagram (Fig.3).

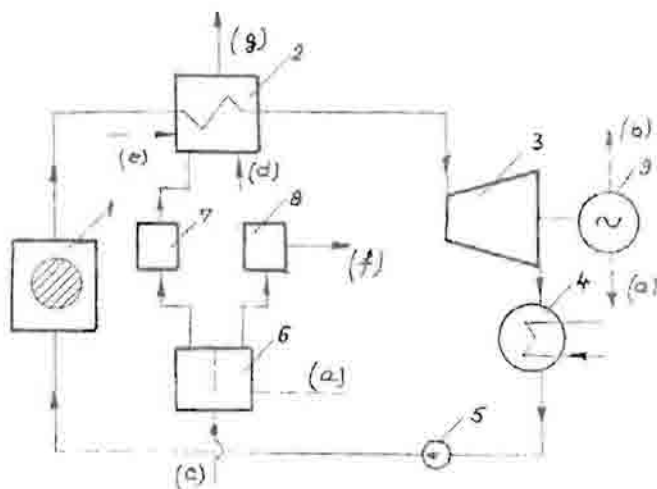


Fig. 3 – The simplified thermal diagram of NPPHC-B: 1–NPSP; 2–boiler for steam superheating; 3–steam turbine; 4–(steam) condenser; 5–feed water pump; 6–electrolyser; 7–hydrogen tank; 8–oxygen tank; 9–electrical generator; (a)–electrical connection; (b)–electric current to user; (c)–water for electrolysis; (d)–air (or H) for combustion; (e)–air for tempering; (f)–O for third using; (g)–flue gases.

In a such system the saturated steam produced in 1 is superheated in 2 and introduced in turbine 3 (with superheated steam) where it is expanded until the pressure of condenser 4. Condensate from 4 is returned with the help of feed water pump 5 to NPSP – position 1, and thus is closed this thermal circuit which has a conventional structure for a NPP where saturated steam produced in NPSP is superheated by fuel combustion (see NPP Indian Point – USA).

Assuming that installation of Fig. 3 would operate in a year a period of $(v\tau)$ and it will deliver electrical energy in a time duration $(v-\kappa_B)\tau$ (the meaning of symbols v , κ and τ are the same as of subchapter 3.1 case) to produce H, and the rest of time $(\kappa_B\tau)$ would deliver electrical energy in PS to contribute in satisfying the increasing energy demand of this system in that peak period. The segment from NPPHC-B installation, composed of 6, 7, 8 and 2 positions (inclusively inlets and

exits a, b c, d, e, f and g) operates in the same way with the segment composed of 6, 7, 8 and 9 positions of NPPHC-A installations. The only difference consists in the fact that the installation now analysed (NPPHC-B), boiler 2 is useful for superheating the saturated steam produced in 1, while at NPPHC-A installation, boiler 9 produces superheated steam from the feeding water coming from pump 12. Since saturated steam produced in 1 have a pressure of 45.5 bar, as we have shown at the beginning of this chapter, we accept that at the exit from superheating boiler 2 the steam pressure to be 40 bar, and at the entrance in turbine 3, its value to be of 35 bar. For a pressure of 35 bar the normal temperature value is of 435 °C [8, 10], and for a pressure of 40 bar the normal temperature value is of 440 °C (enthalpy $h_b = 3310$ kJ).

Thus, the steam turbine 3 will have steam parameters at the admission $p_0 = 35$ bar, $t_0 = 435$ °C. For the steam pressure in condenser, we choose value $p_c = 0.043$ bar, similar with that one from the condenser of installation (N) from NPPHC-A (water cooling temperature of 15°C). A preliminary calculation of steam turbine was performed conform indicated proceedings in [10], accepting that in turbine the entire steam flow capacity which is coming from NPSP is received, namely $m_0 = 1044.1$ kg/s.

As a result, we have the power (at the electric generator terminals) $P_{eB} = 920$ MW. Given the very low values of steam parameters at the entrance in turbine, practically the power of 920 MW could be obtained in two turbo units with a power of 460 MW each.

The calculated thermal efficiency of turbine installation is $\eta_{tB} = 0.345$, with little larger than $\eta_m = 0.34$ and smaller than $\eta_{tc} = 0.45$. Of course, this thing is explained on one hand by the difference between the steam parameters at the turbine inlet, in this three cases, and on the other hand, by the fact that the installations (N) and (C) of case A are equipped with an intermediate steam superheating and in case B there is not such superheating.

Applying the same calculations models as of subchapter 3.1 we have finally obtained $\epsilon_B = 0.06$.

The computation results from 3.1; 3.2 and 3.3 are given in table 1.

Table 1

Installation type	P_e	κ	[MW]
NPPHC A1	330	0.567	0.103
NPPHC A2	1036.5	0.343	0.324
NPPHC B	920	0.116	0.060

We observe that NPPHC-A2 is characterised by the highest values of power P_e provided or PS in a period of peak demands and also of global efficiency ϵ .

But such installation can provide electrical energy for a time period shorter than same type of installation of variant I ($\kappa_2 < \kappa_1$). NPPHC-B installation has characteristics (especially ϵ) much below NPPHC-A installations and so, we consider not to discuss it related with the subject analysed in this paper.

4. CONCLUSIONS

4.1. *The human society evolution to a future "livable world"* is presently confronted with two great provocations, namely:

- the exhaustion, in a relatively short time, of conventional fuel resources, used as primary energy sources;
- the alarming increase of noxious and greenhouse gas accumulations in the terrestrial atmosphere.

4.2. *The answer to this two great provocations relies in using, on a large scale, regenerated energy sources and of those unexhausted (named renewable) energies.*

Because, many times, there is a need for energy in other place than where these regenerated resources can be turned to value (for heating, in transportation etc), hydrogen (H) can be used as energy agent. This has the advantage, because by combustion does not produce pollutant gases.

4.3. *The most important primary energy, practically unexhausted, is the nuclear energy.* If used, it has a minimum impact regarding atmospheric pollution. H, as energetic agent, can be produced in large quantities using electrical and/or thermal energy resulted from Nuclear Power Plants(NPPs) operation.

4.4. *NPPs are adequate for constant power operation*, thus they are used mainly to satisfy the basic zone demands of a load curve from a power system (PS) – see Fig.1. This electrical energy produced in NPPs, in order to be able to contribute in satisfying the peak zone demands, some special power installations can be used. In such types of installation, during the periods with reduced electrical energy demands, the nuclear energy can be used to produce H and, in this turn, is used in producing supplementary electrical energy needed in the peak load period, where in PS is required more such type of energy. In principal, these types of installations are composed from a nuclear installation (NPSP) producing steam, containing the Nuclear Reactor (NR), a power unit with turbine operated with saturated steam supplied by NPSP, an electrolyser (to produce H and oxygen) and one or more power units with turbines with superheated steam produced in a boiler where this H is used as fuel. We named these installations Nuclear Power Plants with steam superheating by Hydrogen Combustion, shortly NPPHC.

4.5. *In this paper, three such possible installations were analysed*, all having as a basic element, NPSP of NPP Cernavoda, with thermal power of 2062 MW and turbo unit with saturated steam turbine, having an electric power of 706.5 MW. The corresponding turbo unit is made in Romania on the base of General Electric technology.

Among the installations compared on energetic criteria we should keep two in mind, one of which is more advantageous from the point of view of longer time duration in peak load operation, and the other is more advantageous from the point of view of power and energetic efficiency. These installations are equipped with superheated steam turbine of 330 MW, made also in Romania.

4.6. *All the problems approached in this paper was analysed only of energy efficiency point of view.* For the purpose to choose a technical solution must to take into consideration also economical elements as investment and operation expenses.

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REFERENCES

1. V. Andrei, S. Pall, *The project The project Yucca Mountain – progress in the geological storage of radioactive waste*, Nuclear Power Journal, **13**, 1–2 (2002).
2. M. Cârdu, M. Baica, *The hydrogen – ideal energy vector from the ecological point of View*, Symposium “Man and environment”, “Politehnica” University of Timișoara, 3-th Edition, 8 November 2004.
3. ***, *Energy for tomorrow's World – Acting Now ! WEC Statement 2000*, Atalink Projects Ltd., WEC, London, 2001.
4. C. Podașcă, A. Stoian, N. Verciuc, *Proгноza cererii de energie electrică în contextul planului de afaceri*, Electrica, **3**, pp. 30–36 (2002).
5. C. Bilegan, Ș. Pall, *Producerea de hidrogen utilizând energia nucleară, pentru o dezvoltare durabilă în secolul XXI*, Energia Nucleară, **14**, 3–4, pp. 47–49 (2002).
6. M. Cârdu, V. Atanasiu, *Results of the international cooperation in the thermopower Equipment field*, Energy Conversion and Management, **35**, 9, pp. 815–825 (1994).
7. G. Creța, *Turbine cu abur și cu gaze*, Editura Tehnică, București, 1996.
8. I. Rotaru, I. Bucur, *CNE-PROD CERNAVODA–obiectiv energetic modern, curat, sigur și eficient*, Energetica, **50**, 5, pp. 198–200 (2002).
9. C. Ungureanu, *Generatoare de abur pentru instalații energetice clasice și nucleare*. Editura Didactică și Pedagogică, București, 1977.
10. T. Grecu, M. Cârdu, I. Nicolau, *Turbine cu abur*, Editura Tehnică, București, 1976.