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**Title** **FLEXIBILITY OF POWER GENERATION AND POSSIBILITIES FOR FEASIBLE UPGRADES OF COAL POWER PLANTS: A CASE OF THE ELECTRIC POWER INDUSTRY OF SERBIA**

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**Abstract** Abstract This paper deals with the current status and possibilities for a feasible improvement of the flexibility of power generation fleet within the Electric Power Industry (EPS) in the Republic of Serbia. The flexibility of the current EPS power generation system is analysed by use of appropriate well established deterministic metrics. In this regard, the normalized flexibility indicator for each power unit is evaluated taking into account ramp up and ramp down power rates as well as the unit operating range. As expected, the hydro power units are highly flexible with normalized flexibility indicator reaching the values as high as 0.78 (on the scale from 0 to 1). On the other side, the generating units in power plants fueled with lignite are of low flexibility - especially the units in the largest thermal power plants where the flexibility indicator is well below 0.2. This issue can represent a serious constraint for operation of these units in conditions of variable demand. It is, also, a drawback for the future implementation of renewable energy sources with intermittent power generation. For that reason, the attention is focused on the flexibility analysis of units in lignite fueled power plants. The analysis indicates that operating range (formulated as the difference between maximal and minimal net electric power) is a stronger limitation factor for the flexibility of these power generation units than the value of ramp up / down rate. Therefore, the efforts for flexibility enhancement should be directed to lowering of the value of unit minimal electric power or increase of the maximal power. This conclusion is in accordance with findings reported in number of documents about the flexibility of coal fired power plants in other countries. With the goal to increase the range of operational power, various technical measures for retrofitting of boiler and turbine plant as well as redesigning of pressure parts are considered in open literature. Despite their undoubtedly positive impact on flexibility improvement, some of these measures (for example, implementation of additional boiler or replacement of thick-wall by thin-wall unit components) would represent such a drastic surgery for the aged lignite fueled power fleet that might not be considered as feasible. For that reason, we propose considerations of sophisticated technical measures which contribute to the flexibility increase, but do not require too high retrofitting costs. This paper presents and analyses innovative



technical solutions, which lead to the flexibility increase of power units. The solutions are based on (i) advanced operational procedures for feedwater redistribution between the main feedwater line with high pressure heaters and the feedwater line with an additional economizer at the utility steam boiler (ii) installation of additional economizers for the recovery of flue gas waste heat and (iii) implementation of steam accumulators which serve either as thermal energy storage for surplus steam or as heat source for feedwater heating depending on required unit power.

Rad se bavi tekućim statusom i mogućim poboljšanjima fleksibilnosti proizvodnih kapaciteta u okviru Elektroprivrede Srbije (EPS). Fleksibilnost sadašnjeg sistema za proizvodnju električne energije u EPS-u je analizirana primenom dobro uspostavljene metodologije zasnovane na determinističkom pristupu. U tom smislu, normalizovani indikator fleksibilnosti je određen za svaku proizvodnu jedinicu uzimanjem u obzir brzine porasta tj. smanjenja snage kao i dopuštenog opsega promene snage. Očekivano, proizvodne jedinice hidroelektrana poseduju visok stepen fleksibilnosti – normalizovani indikator fleksibilnosti dostiže vrednosti i do 0,78 (na skali od 0 do 1). Sa druge strane, blokovi u termoelektranama na lignit imaju nizak stepen fleksibilnosti. Ovo je posebno izraženo u blokovima sa najvećom snagom, gde je vrednost normalizovanog indikatora fleksibilnosti značajno ispod 0,2. Niski stepen fleksibilnosti može da predstavlja ozbiljno ograničenje pri radu blokova na lignit u uslovima promenljive snage potrošnje. Takođe, ovakvo stanje predstavlja nepogodnost za budući energetski sistem u kome se planira povećanje udela obnovljivih izvora energije sa izrazito promenljivom proizvodnjom struje. Iz tog razloga, potrebno je posvetiti posebnu pažnju fleksibilnosti parnih blokova na lignit. Analiza parametara blokova na lignit pokazuje da je dopušteni opseg promene snage (definisana kao razlika maksimalne i minimalne snage na pragu elektrane) faktor koji više ograničava fleksibilnost nego brzina promene snage. Dakle, napori za povećanje fleksibilnosti parnih blokova treba da budu usmereni na smanjenje tehničkog minimuma ili povećanje maksimalne snage. Ovaj zaključak je u skladu sa analizama objavljenim u brojnim dokumentima o fleksibilnosti termoelektrana na ugalj u drugim zemljama. U literaturi su predstavljena različita tehnička rešenja za rekonstrukciju kotla i turbopostrojenja kao i komponenti pod visokim pritiskom, koja imaju za cilj povećanje opsega promene snage bloka. Uprkos njihovom nesumnjivo pozitivnom efektu na povećanje fleksibilnosti bloka, neke od ovih mera (kao na primer, ugradnja dodatnog kotla, korišćenje komponenti sa tankim umesto debelim zidovima) zahtevaju velike promene koje na već starim blokovima termoelektrana na ugalj ne bi bile izvodljive, niti bi bile ekonomski opravdane. U tom smislu, predlažu se tehnička rešenja koja povećavaju fleksibilnosti blokova, a ne zahtevaju izuzetno visoke troškove za njihovu realizaciju. U ovom radu su izložena i analizirana tehnička rešenja kojima se postiže povećanje fleksibilnosti parnih blokova. Predstavljena rešenja su zasnovana na (i) unapređenim operativnim procedurama za redistribuciju napojne vode između linije napojne vode visokog pritiska i linije napojne vode ka već ugrađenom dodatnom ekonomajzeru (ii) ugradnji dodatnih zagrejača vode za iskorišćenje toplote dimnog gasa i (iii) ugradnji akumulatora pare koji bi, u zavisnosti od zahtevane snage bloka, služio ili za akumulaciju viška toplotne energije ili kao izvor za zagrevanje napojne vode.

**Keywords** power generation, flexibility, coal-fired power units, feasible plant retrofitting

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