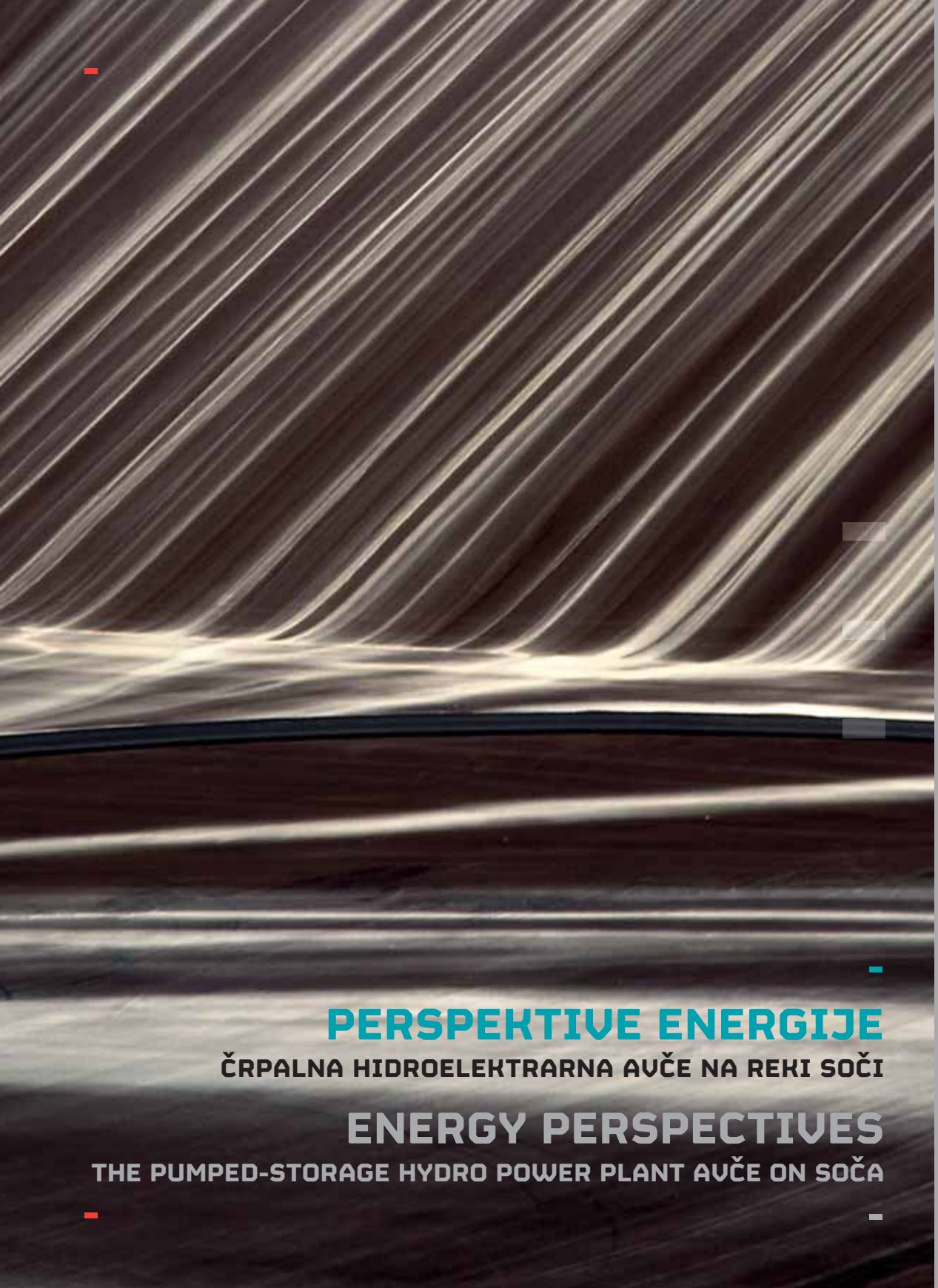

PERSPEKTIVE ENERGIJE

ČRPALNA HIDROELEKTRARNA AVČE NA REKI SOČI

ENERGY PERSPECTIVES

THE PUMPED-STORAGE HYDRO POWER PLANT AVČE ON SOČA

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SENG
SOŠKE ELEKTRARNE NOVA GORICA d.o.o.
Skupina GEN-I

Energy

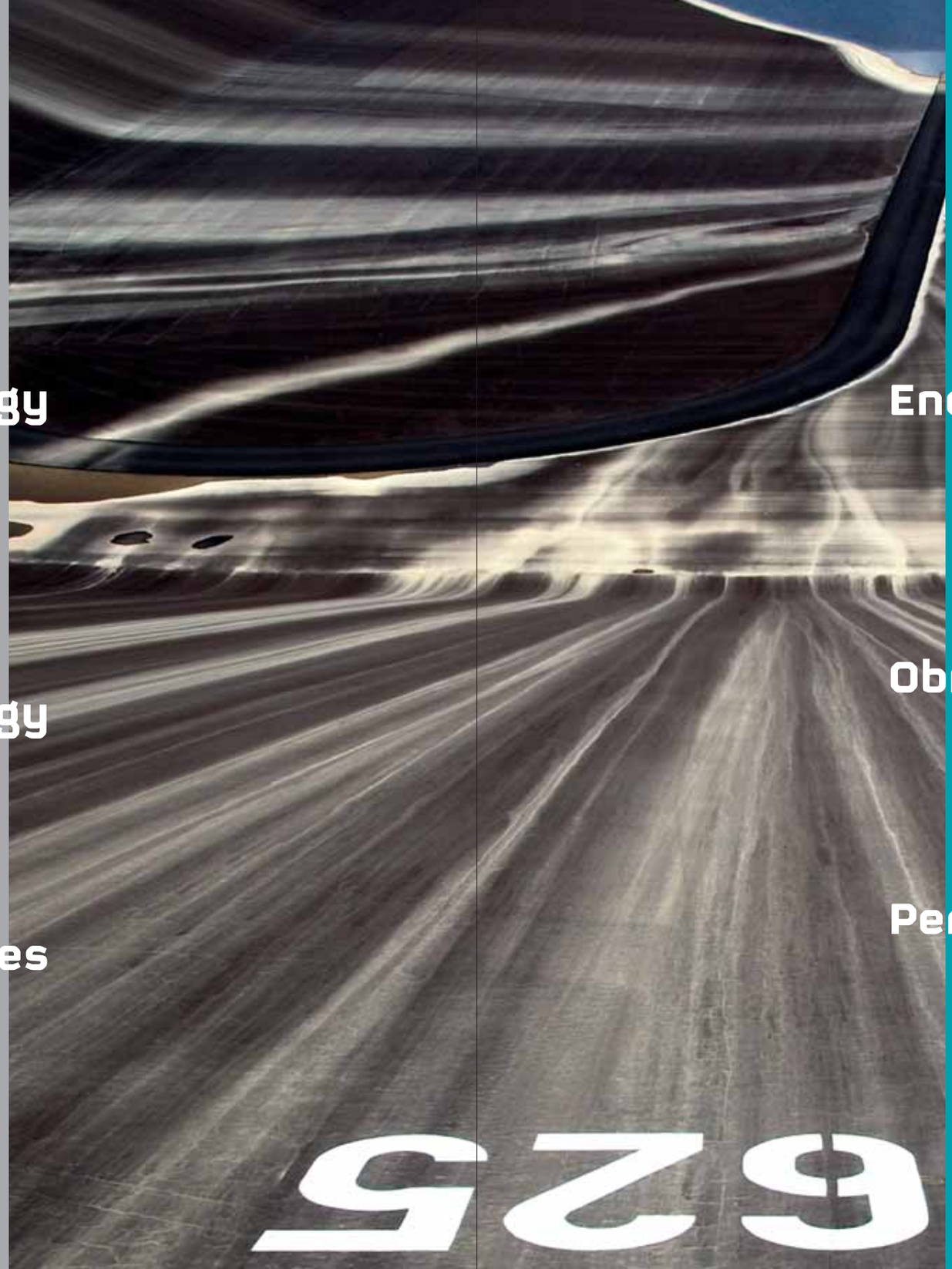
is everywhere around us
and in everyone of us.
Man is excited by natural resources.
By creative energy.
He explores them,
exploits them and changes the world.

Renewable energy

inspires those,
who comprehend the nature as their partner,
who build their environment respecting the future,
who always give more than they momentarily take.

Energy Perspectives

are changing.
Only man,
with his energy of thoughts and actions,
is able to preserve the balance of all energies.



Energija

je povsod okrog nas
in v vsakem od nas.
Človeka vznemirjajo naravni viri.
Z ustvarjalno energijo
jih raziskuje, črpa in spreminja svet.

Obnovljiva energija

navdihuje človeka,
ki naravo dojema kot partnerja,
ki okolje gradi s spoštovanjem prihodnosti,
ki vselej daje več, kot trenutno vzame.

Perspektive energije

se spreminjajo.
Edino človek
lahko z energijo misli in dejanj
ohrani ravnovesje vseh energij.

SENG – Soške elektrarne Nova Gorica
SENG – Soča Power Plants Nova Gorica

Družba Soške elektrarne Nova Gorica d.o.o., s krajšim imenom SENG d.o.o., je specializirana za proizvodnjo tako imenovane modre energije, električne energije iz obnovljivega vodnega vira. Družba ima koncesijo za izkoriščanje hidroenergetskega potenciala Soče, Idrijce, Bače in drugih vodotokov tega porečja. Pet velikih in 21 malih hidroelektrarn s skupno močjo 160 MW letno proizvede 520 GWh električne energije.

Sodobno, poslovno uspešno in razvojno naravnano podjetje ambiciozno uresničuje svoje široko poslanstvo v skupini Holdinga Slovenske elektrarne. Poleg proizvodnje električne energije je sožitje z okoljem eden njegovih najpomembnejših poslovnih ciljev. Ohranjanje naravnega ravnovesja s premišljenim načrtovanjem posegov v okolje, skrbno vzdrževanje proizvodnih in drugih infrastrukturnih objektov, omogočanje njihove večnamenske izrabe in zgledno vključevanje v družbeno življenje uvrščajo SENG med družbeno najbolj odgovorna podjetja v državi.

SENG je tehnološko napredna in tržno usmerjena družba, ki skrbi za nenehen razvoj znanj in tehnoloških zmogljivosti. Uspešno poslovanje ji omogoča obsežna vlaganja v obnovo obstoječih in gradnjo novih hidroelektrarn. V letu 2009 je družba zaključila petletni projekt izgradnje črpalne hidroelektrarne Avče.

The Company of Soške elektrarne Nova Gorica d.o.o. (Soča Power Plants Nova Gorica ltd.), shorter SENG d.o.o., is specialised for the production of the so called blue energy, i.e. the electricity produced from the renewable water sources. The company was awarded the concession contracts for the exploitation of the hydroenergetic potential of the rivers of Soča, Idrijca, Bača and other water courses of this river basin. The annual production of electricity of its five large and twenty-one small hydroelectric power plants with a total power of 160 MW amounts to 520 GWh.

Modern, successful and development oriented company, allied within the Holding Slovenske elektrarne d.o.o. (Slovene Hydroelectric Power Plants Holding, ltd.), fulfils its comprehensive mission ambitiously. Beside the electricity production the cohabitation with its operational environment presents one of the company's most important business goals. The fact of the company's preserving of natural balance through thoroughly planned activities, affecting the environment, its attentive maintenance of production and other infrastructure facilities and enabling of its multipurpose exploitation and exemplary involvement into social life, rank SENG among the socially most responsible companies in Slovenia.

SENG is a technologically advanced and market oriented company, taking good care of a constant development of its know-how and technological capacities. The company's successful operation enables it to largely invest both into renovation of the existing, and construction of new hydro power plants. In 2009, the company concluded its five-year construction project of the Pumped-Storage Hydro Power Plant Avče.

1_ Struga reke Soče
1_ The Soča River bed

Sodobni izzivi proizvodnje energije
Contemporary Challenges Facing the Energy Production

Slovenski elektroenergetski sistem določajo njegove proizvodne zmogljivosti in tržni pogoji na meddržavnem trgu električne energije. Zgodovinsko pogojena neugodna struktura proizvodnih zmogljivosti se v pogojih odprtega trga odraža v velikem razkoraku med cenami električne energije v času dnevnih konic in v času nizke porabe ter v skokih cen električne energije ob nenadnih izpadih proizvodnje večjih elektrarn. Zaradi neugodne strukture proizvodnih zmogljivosti Slovenija proizvede veliko nočnih viškov energije, ki na trgu dosegajo nizke cene.

V takih razmerah se je rodila ideja o izgradnji črpalne hidroelektrarne, ki s svojim delovanjem omogoča bolj ekonomično izrabo vodnih virov. V času nizkih cen električne energije, ponoči in ob koncu tedna, črpalna hidroelektrarna porablja električno energijo za črpanje vode v akumulacijski bazen, v času visoke porabe in s tem visokih cen električne energije pa akumulirano vodo porablja za proizvodnjo električne energije.

Zamisel o izgradnji črpalne hidroelektrarne Avče je osvetlila tudi druge prednosti. Zaradi morfoloških, hidroloških in geoloških danosti na izbrani lokaciji ter možnosti izrabe obstoječe rečne akumulacije je v primerjavi z drugimi aktualnimi naložbami v elektroenergetske zmogljivosti projekt izgradnje črpalne hidroelektrarne Avče na reki Soči predstavljal tudi ugodno naložbo.

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The Slovene electricity supply system is determined by its industrial capacities and market conditions on the international electric power market. In the open market conditions the historically conditioned unfavourable structure of industrial capacities is reflected in large electricity power prices gaps during daily peak hours and low consumption hours as well as in the electricity power prices leaps due to the unexpected production failure of larger power plants. Due to the unfavourable industrial capacities structure, Slovenia produces large quantities of night energy surpluses, fetching low prices on the market.

In these circumstances the idea about the construction of the pumped-storage hydro power plant, enabling more economical water resources recovering, was born. In the low electricity prices periods, especially at nights and during the weekends, the pumped-storage hydro power plant uses the electric power to pump the water into the water-storage reservoir, whereas in the high consumption and thus the high electricity prices periods the plant uses the accumulated water to generate the electricity.

The idea about the construction of the Pumped-Storage Hydro Power Plant Avče also threw favourable light upon a handful of some other advantages. In comparison to other actual electricity facilities investments, the construction project of the Pumped-Storage Hydro Power Plant Avče on Soča also turned out to become a favourable investment due to its chosen sitting's morphological, hydrological and geological characteristics as well as the exploitation possibilities of the existing river's accumulation.

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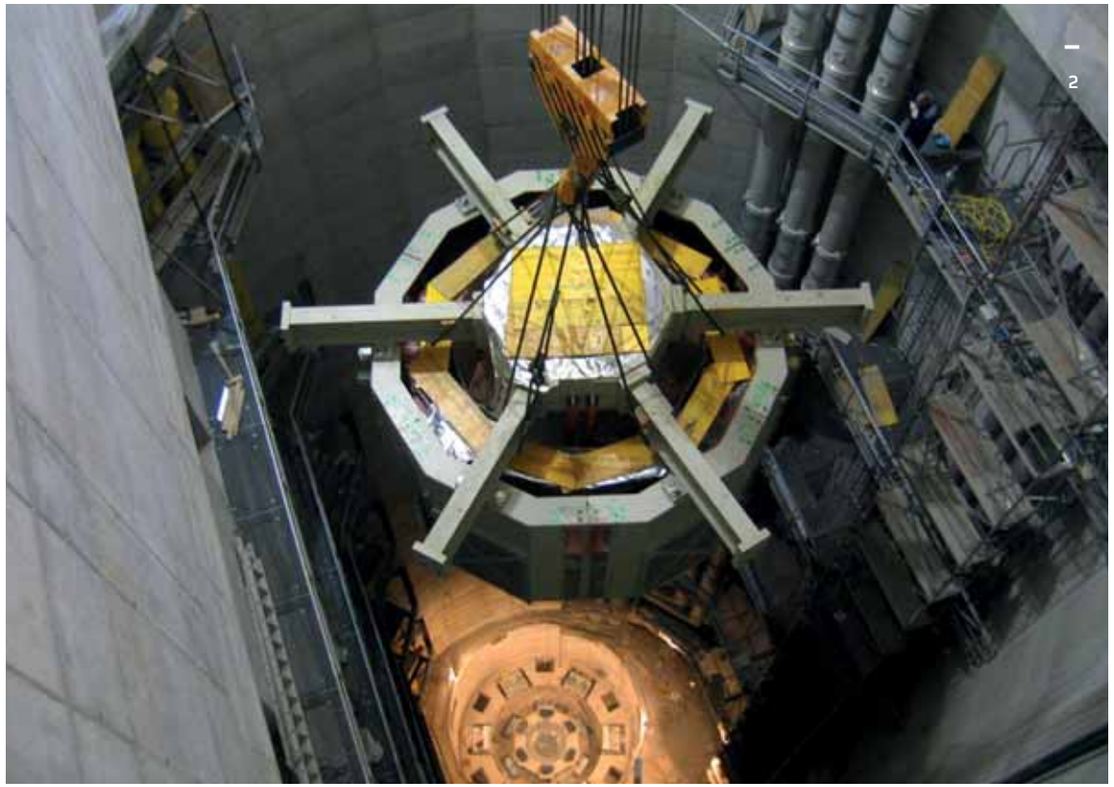

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2_ Spust statorja v strojnični jašek
2_ The launching of the stator into the powerhouse shaft

Perspektive nove elektrarne
The New Power Plant's Perspectives

Črpalna hidroelektrarna Avče, prva tovrstna hidroelektrarna v Sloveniji in ena izmed prvih reverzibilnih črpalnih elektrarn s spremenljivo hitrostjo delovanja v črpalnem režimu v Evropi, predstavlja pomembno pridobitev širšega pomena. S svojo sodobno tehnologijo in domišljeno zasnovo bo dolgoročno pozitivno vplivala na proizvodnjo električne energije v Sloveniji, hkrati pa prinaša tudi vrsto drugih pozitivnih gospodarskih in družbenih učinkov.

Nova elektrarna bo pomembno prispevala k reševanju problematike neugodne strukture proizvodnje električne energije v Sloveniji, saj bo proizvajala tako imenovano vršno energijo, ki jo v Sloveniji stalno primanjkuje. Z bolj ekonomično izrabo energije, ki jo proizvede veriga hidroelektrarn na reki Soči, bo prispevala k večji poslovni uspešnosti družbe SENG in s tem celotnega Holdinga Slovenske elektrarne. Nova elektrarna prinaša tudi dodatne storitve v elektroenergetskem sistemu: sistemske rezerve, regulacijo napetosti, kompenzacijo jalove energije ter izboljšanje obratovanja elektroenergetskega sistema.

Z domišljeno umestitvijo v prostor prinaša nova elektrarna tudi nove razvojne možnosti demografsko ogroženemu območju Banjške planote. Akumulacija na Kanalskem Vrhu je dobrodošel potencial razvoja bivalnega okolja in turističnega razvoja na tem območju.

Gradnja črpalne hidroelektrarne Avče je imela zaradi zahtevne in obsežne investicije ter visokega deleža slovenskih izvajalcev pozitiven vpliv na celotno slovensko gospodarstvo.

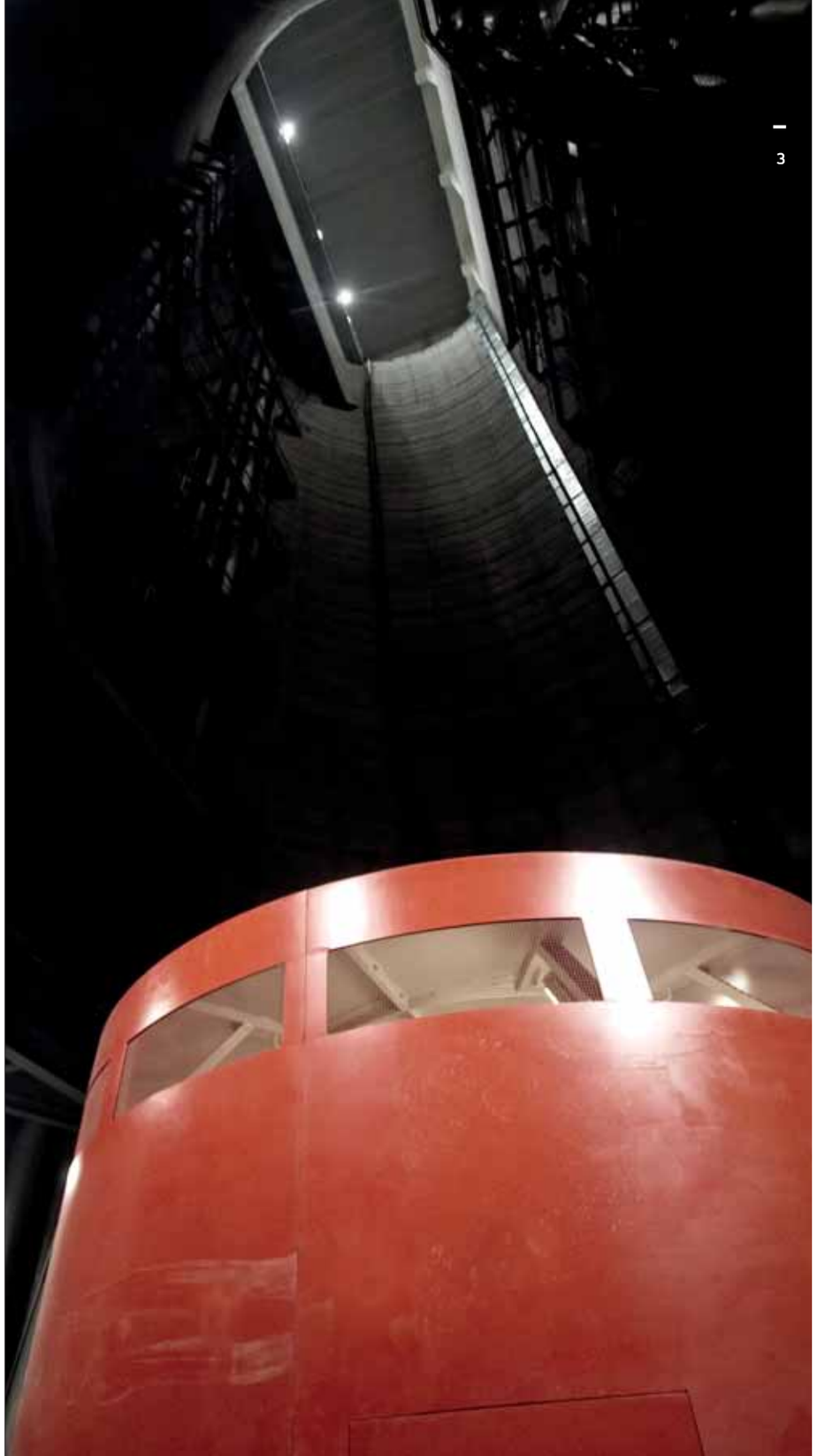
The Pumped-Storage Hydro Power Plant Avče, the first power plant of its kind in Slovenia and one of the first reversible pumped-storage hydro power plants with the variable pumping regime operation rate in Europe, presents an important acquisition in the broader meaning too. With its up to-date technology and thoughtful conception, it offers a possibility of a long-term positive influence on the electricity generation in Slovenia, contributing at the same time to a whole range of other positive economic and social effects.

The new power plant will also contribute to a positive solution of the unfavourable electricity generation structure problems in Slovenia, as it is going to generate the so called peak energy, the lack of which is constantly affecting Slovenia.

A more economical recovery of energy, generated by the hydro power plants chain on the Soča River will enable a greater business performance of the SENG Company and thus of the entire Slovene Hydroelectric Power Plants Holding as well. The new power plant will also offer some additional services within the electricity system, i.e. systematic reserves, frequency regulation, idle energy compensation and electricity system operation improvement.

Due to its thoughtful geographic location, the new power plant will also bring some new development possibilities to the demographically endangered area of the Banjška planota plateau. The water reservoir on Kanalski Vrh presents a welcome potential for residential environment and tourist development in this area.

Due to its large investment volume and high share of Slovene contractors, the construction of the Pumped-Storage Hydro Power Plant Avče also positively influenced the entire Slovene economy.



3_ Strojnični jašek z notranjim premerom 18 m in globine 80 m

3_ The 80 m deep powerhouse shaft in the inner diameter of 18 m

Umeščanje elektrarne v okolje
The Power Plant's Geographic Positioning

Postopek umeščanja objekta črpalne hidroelektrarne Avče v prostor je potekal v več korakih in v skladu s predpisi ter drugimi standardi sodobnega ravnanja s prostorom. Kljub številnim korakom in vključevanju vseh zainteresiranih javnosti je bil lokacijski načrt za energetski objekt skupnega pomena sprejet v 16-ih mesecih, gradbeno dovoljenje je bilo izdano 21. 9. 2004. Učinkovito vodenje postopkov je pomembno vplivalo na časovni potek sprejemanja dokumentov za gradnjo, s tem pa tudi na investicijsko vrednost in ekonomiko projekta.

V postopku umeščanja objekta v prostor so bile izdelane različne študije, ki so zajele vsa strokovna področja, potrebna za izdelavo projektne in prostorske dokumentacije tako zahtevnega objekta. Idejni zasnovi nove elektrarne je najprej sledila okoljevarstvena strateška presoja idejne zasnove in presoja vplivov na regionalni in urbani razvoj. Poleg vplivov na okolje so načrtovalci raziskovali tudi možnosti razvoja turizma po izgradnji elektrarne. Natančne študije so bile osnova načrtovanja gornje akumulacije črpalne hidroelektrarne, določitve optimalnega obsega črpanja vode in določitve optimalne instalirane moči elektrarne. Vse študije so upoštevale tudi vse možne vplive na delovanje preostalih proizvodnih enot Holdinga Slovenske elektrarne. Na osnovi vseh teh študij in inženirsko-geološkega poročila o izvajanju preiskav na območju gradnje je bil izdelan idejni projekt črpalne hidroelektrarne Avče.

V postopek priprave in sprejema prostorske dokumentacije je bila v največji možni meri vključena tudi lokalna skupnost. Zgledno sodelovanje v zgodnji fazi načrtovanja je oblikovalo temelj uspešnega sobivanja v skupnem prostoru.

The Pumped-Storage Hydro Power Plant Avče facility geographic positioning procedure was conducted in several steps and in accordance with regulations and other standards of the up to-date environment handling. In spite of the numerous steps that had to be taken and the thorough integration of all the interested publics, the detailed site plan for this collectively significant energy generating facility was adopted in 16 months, whereas the building permit was issued on 21 September 2004. The efficient conduct of procedure significantly influenced the time course of the building documents adoption and thus the investment value and project's administration as well.

Within the procedure of the facility's geographical positioning several different studies were prepared, which comprised all the particular disciplines, necessary for the elaboration of project and spatial documentation of such a demanding facility. After the new power station concept was made, it was first followed by its strategic environmental protection estimation as well as influences on regional and urban development estimation. Beside the environmental impacts, the planners also contributed their research on the possibilities of the development of tourism after the power plant construction. The precise studies served as basis for the designing of the upper water storage of the pumped-storage hydro power plant, optimal water pumping volume and optimal installed plant power determination. All the studies also took into consideration all the possible influences on the operation of all the rest production units of the Slovene Hydroelectric Power Stations Holding. On the basis of all the mentioned studies and the engineering geological report on the researches carried out in the construction area the outline scheme of the Pumped-Storage Hydro Power Plant Avče was made.

The preparation of spatial documentation was also, and to the largest possible extent, confided to the local community. The exemplary cooperation in the earlier phase of design formed a foundation of a successful coexistence within the common use area.

4_ Zgornji akumulacijski bazen, zgrajen v naravni kotanji v bližini vasi Kanalski Vrh

4_ The upper water-storage reservoir, built in the natural basin near the village of Kanalski Vrh

Gradnja elektrarne
Power Plant's Construction

5

5_ Asfaltiranje brežin zgornjega akumulacijskega bazena

5_ Asphalting of the upper water-storage reservoir embankments

Po pridobitvi gradbenega dovoljenja septembra 2004 so se decembra istega leta pričela pripravljalna dela, ki so obsegala pripravo platojev na spodnjem glavnem gradbišču, na območju strojnice in na zgornjem gradbišču v območju akumulacije, izgradnjo dostopnih in povezovalnih cest ter vse druge komunalne infrastrukture. Gradnja objekta se je pričela avgusta 2005 in se je zaključila avgusta 2009. Sledili so zagonski in funkcionalni preizkusi, konec oktobra je bil uspešno izveden tehnični pregled, decembra 2009 pa je objekt dobil dovoljenje za enoletno poskusno obratovanje.

After the acquisition of the building permit in September 2004, in December of the same year the site preparation works started, comprising lower main building site, powerhouse area and upper building site around the water storage plateaus preparation as well as the accessible and connecting roads and all the other municipal infrastructure construction. The facility's construction started in August 2005 and ended in August 2009. Start-up and functional tests followed as well as technical inspection, which was carried out in the end of October. In December of 2009, the facility finally acquired its one-year preliminary-running permit.

Nove tehnologije

Gradnja črpalne hidroelektrarne Avče je bila velik strokovni izziv. Za večjo kakovost gradnje so bile uporabljene nekatere nove gradbene tehnologije in rešitve. Pri gradnji nasutih pregrad zgornjega akumulacijskega bazena sta bili v Sloveniji prvič uporabljeni tehnologija kontinuiranih površinskih dinamičnih meritev zgoščenosti nasipnih plasti (Continuous Compacting Control) in AccuGrade GPS metoda za meritev izravnave zemeljskih površin. Tudi izvedba asfaltne obloge notranjosti zgornjega bazena je zahtevala nove rešitve. Uporabljena je bila posebna tehnologija s prilagojeno opremo za vgradnjo asfaltnih plasti pri večjih naklonih. Pri obsežnih betoniranjih podzemnih jaškov in tunelov so bile uporabljene specialne recepture betonov in sodobna tehnologija vgradnje samozgoščevalnih betonov.

The New Technologies

The construction of the Pumped-Storage Hydro Power Plant Avče presented a genuine professional challenge indeed. In order to ensure a better quality of construction, some new construction technologies and solutions were used. For the construction of the earth coffer dams of the upper water-storage reservoir the Continuous Compacting Control technology for the dam layers and the AccuGrade GPS method for the land levelling measurements were used in Slovenia for the first time. The execution of the asphalt lining for the upper water-storage reservoir interior demanded the application of new solutions as well. In this case, a special technology was used with the adjusted equipment for the installation of asphalt layers used for larger inclinations. For the extensive concreting of underground shafts and tunnels special concrete mixes recipes and up to-date technology of self-compacting concretes installation were used.

Objekti črpalne hidroelektrarne Avče
The Pumped-Storage Hydro Power Plant Facilities

Zgornji akumulacijski bazen

Bazen prostornine 2.200.000 m³ je zgrajen v naravni kotanji v bližini vasi Kanalski Vrh, razteza se na površini približno 15 hektarjev. Na severni in južni strani je omejen z naravnimi pobočji, na severozahodni in jugozahodni strani pa sta z izkopnim materialom zgrajeni zemeljski pregradi višine 10 m in 15 m. Vodotesnost akumulacijskega bazena je dosežena z asfaltno oblogo, vgrajeno na predhodno izdelano 30 cm debelo drenažno plast drobljenca. Asfaltna obloga je dvoslojna, in sicer po 8 cm debeline nosilne plasti in zaporne plasti na poševnini ter po 7 cm debeline vsakega sloja na horizontalnem delu bazena. Za zaščito asfaltne obloge proti staranju, UV žarčenju, učinku in izhlapevanju hlapljivih vsebin ter pokanju je nanešen premaz iz vročega bitumenskega mastiksa.

The Upper Water-Storage Reservoir

The reservoir with the volume of 2,200,000 m³, built in the natural basin near the village of Kanalski Vrh, spreads over the area of approximately 15 hectares. To North and South it is bounded by natural slopes, whereas to Northwest and Southwest for that purpose the 10 m and 15 m high embankments were constructed from the dredged material. The water tightness of the water-storage reservoir was achieved with the asphalt lining, built in the previously made 30 cm thick drainage layer. The asphalt lining is made of two layers, i.e. the 8 cm thick bearing and shut-off layers on the slope as well as the 7 cm thick layers on the reservoir's horizontal part. For the asphalt lining protection against ageing, UV radiation, effect and evaporation of vaporizable substances and cracking a hot bituminous cover of mastics was used.

Dovodni tunel, vodostan in zapornična komora

697 m dolg dovodni tunel povezuje zgornji bazen s tlačnim cevovodom. Tunel premera 3,90 m je na celotni dolžini obdan z armirano betonsko oblogo, na odseku med zapornično komoro in dušilko pa je dodatno vgrajena jeklena obloga v dolžini cca. 100 m. Pred prehodom dovodnega tunela v jekleni tlačni cevovod je zgrajen vodostan, ki ga sestavljajo spodnja komora dolžine 117 m in premera 3,5 m, jašek višine 41 m in premera 4,5 m ter zgornja komora dolžine 40 m in dimenzijami v prerezu 4,5 m x 4,5 m. Zapornična komora višine 14,5 m s tlorisom 8,0 m x 9,0 m je armirano betonska zgradba. Temeljni del zapornične komore, dimenzij v tlorisu 5,5 m x 10,3 m in spremenljive višine med 7 m in 9 m, predstavlja povezavo med dovodnim tunelom, jeklenim cevovodom in zgornjim delom zapornične komore.

Headrace Tunnel, Surge Tank and Valve Chamber

A 697 m long headrace tunnel connects the upper reservoir with the pressure penstock. On its entire length the tunnel in the diameter of 3.90 m is rounded with the ferroconcrete lining, whereas on the section between the valve chamber and throttle, the steel lining in the approximate length of 100 m is additionally built in. In front of the headrace tunnel passage to the steel pressure penstock the surge tank is built, consisting of 117 m long lower chamber in the diameter of 3.5 m, 41 m long shaft in the diameter of 4.5 m and 40 m long upper chamber with the cross-section dimensions of 4.5 m x 4.5 m. The valve chamber with the height of 14.5 m and the ground plan of 8.0 m x 9.0 m is a ferroconcrete structure. The basic part of the valve chamber with the ground plan dimensions of 5.5 m x 10.3 m and the variable height between 7 m and


6


7


8

6_ Jeklena obloga sifona
6_ Siphon steel lining

7_ Zgornji akumulacijski bazen prostornine 2.200.000 m³
7_ The upper water-storage reservoir with the capacity of 2,200,000 m³

8_ Nadzemni del tlačnega cevovoda, ki povezuje dovodni tunel s strojnico
8_ The pressure penstock overhead part, connecting the headrace tunnel and powerhouse

Tlačni cevovod

Cevovod dolžine 1.567 m poteka po pobočju Avškega Kuka in povezuje dovodni tunel s strojnico. Trasa tlačnega cevovoda je razdeljena na zgornji odsek nadzemnega cevovoda in spodnji odsek podzemnega cevovoda. Dolvodno se premer cevovoda zmanjšuje od 3,3 m do 2,6 m. Nadzemni del cevovoda v dolžini 862 m je vpet v šest fiksnih podpor, med fiksnimi podporami pa je na razdaljah 20 m podprt s sedli oziroma drsnimi podporami. Od fiksne točke 6 do strojnice poteka cevovod pod zemljo. Na tej točki je cevovod izveden kot prosto koleno, preko katerega preide cevovod v vertikalni jašek globine 190 m in premera 3,1 m. V globini 190 m poteka

9 m, presents a connection between the headrace tunnel, steel penstock and the upper part of the valve chamber.

The Pressure Penstock

The 1,567 m long penstock runs along the Avški Kuk slope and connects the headrace tunnel with the powerhouse. The pressure penstock route is divided into the overhead penstock upper section and the underground penstock lower section. Downstream the penstock diameter reduces from 3.3 m to 2.6 m. The 862 m long overhead penstock part is fitted into the six fixed points, between which it is supported by saddles, located at 20 m distances each. From the fixed point 6 to the po-

cevovod v horizontalnem tlačnem tunelu dolžine 395 m in premera 3,1 m ter nazadnje kot poševni tlačni tunel dolžine 120 m in premera 2,6 m.

Strojnica s strojničnim jaškom

Zgradba strojnice je zgrajena na levem bregu Soče ob izlivu potoka Avščck. Podzemni del predstavlja strojnični jašek z notranjim premerom 18 m in globine 80 m, ki je obdan z meter debelo betonsko oblogo. Etaže jaška so povezane s stopnicami, vgrajeno pa je tudi dvigalo, ki omogoča dostop do vseh etaž.

V jašku je nameščen reverzibilni agregat (črpalka/turbina in motor/generator), ki obratuje z močjo 185 MW v turbinskem režimu in z močjo 180 MW v črpalnem režimu. Agregat je izveden tako, da omogoča spreminjanje hitrosti vrtenja od - 4 do + 4 nazivne hitrosti 600 vrtljajev na minuto (varspeed). To omogoča večje prilagajanje razmeram v elektroenergetskem sistemu in razpoložljivi količini vode. Za nemoteno delovanje agregata so vgrajeni tudi sodobni pomožni sistemi, kot so sistem vodnega hlajenja strojne in elektro opreme, sistem drenaže in odvodnjavanja strojničnega jaška ter sistem za preskrbo in prečiščevanje olja. Poleg navedenih pomožnih sistemov je instaliran tudi sistem prvega polnjenja tlačnega cevovoda, ki se bo uporabljal tudi v času večjih vzdrževalnih del. Vsi sistemi so izvedeni v skladu s standardi kakovosti in zahtevami nemotenega ter varnega delovanja.

Nadzemni del strojnice na koti 120,00 m obsega montažno halo z mostnima dvigaloma nosilnosti 300 t in 15 t, naprave vzbujalnega sistema ter pomožne prostore za ostalo elektro opremo (transformatorji, stikališče, generatorski odklopnik, dizel agregat ...). V kletnih prostorih na koti 113,00 m so elektro razvodi, oljni rezervoarji, akumulatorji in pomožna skladišča.

Elektrarna je priključena na elektroenergetsko omrežje preko 110 kV stikališča in glavnega transformatorja. 110 kV stikališče je izvedeno v GIS (Gas

werhouse the penstock route runs underground. On this point the penstock is executed as a free standing angle, over which the penstock passes over into the 190 m deep vertical shaft in the diameter of 3.1 m. At a depth of 190 m the penstock runs through the 395 m long horizontal pressure shaft in the diameter of 3.1 m and finally as a 120 m long inclined pressure shaft in the diameter of 2.6 m.

The Powerhouse with the Powerhouse Shaft

The Powerhouse facility is constructed on the Soča River left bank near the Avščck brook outfall. Its underground part consists of the 80 m deep powerhouse shaft in the inner diameter of 18 m, rounded with the one meter thick concrete lining. All the shaft floors are accessible from both the staircases and the built-in elevator.

Inside the shaft the reversible aggregate (pump/turbine and motor/generator) is installed, operating with the power of 185 MW in the turbine operation mode and in the power of 180 MW in the pump operation mode. The aggregate instalment enables the rotation speed variability from – 4 to + 4 nominal speed of 600 rpm. This also enables a better adjustment to the electricity system situation and the available amount of water. For the aggregate smooth functioning the up to-date auxiliary systems are also installed, such as machine and electrical equipment water cooling system, powerhouse shaft drainage system and oil supply and refining system. Beside the above mentioned auxiliary systems, the pressure penstock first filling system is also installed, to be applied during the extensive maintenance operations. All the systems are executed in compliance with the quality standards and safe and smooth operation requirements.

The powerhouse overhead part, situated at the height of 120.00 m, includes the assembly hall with the cranes with the bearing capacity of 300 t and 15 t, excitation system devices as well as auxiliary

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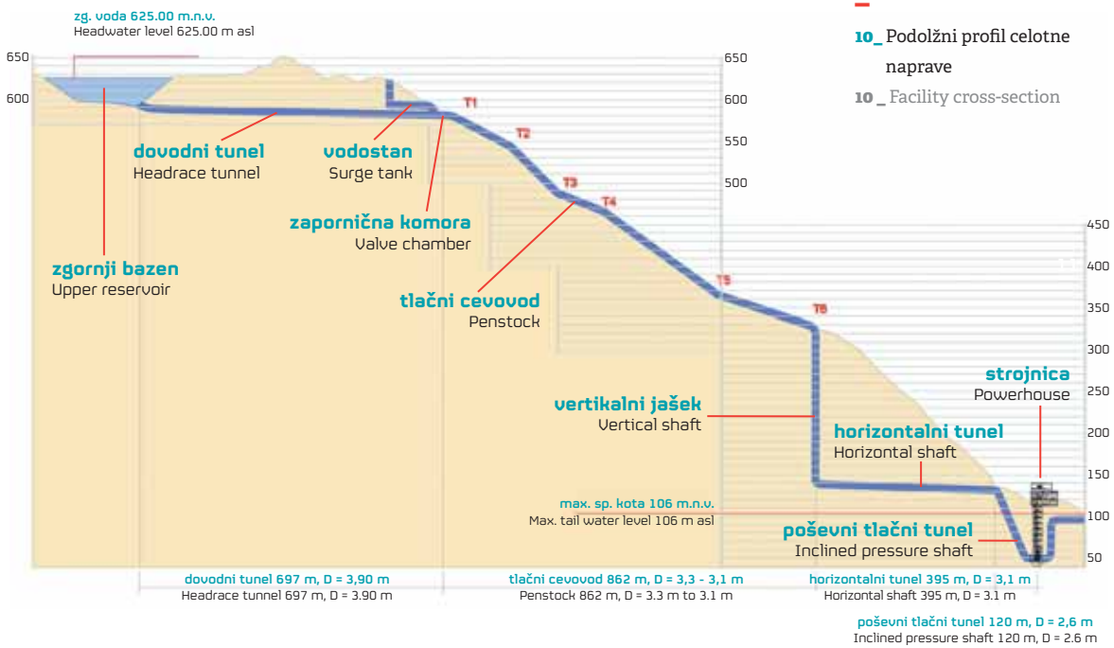
9_ Strojnični jašek z generatorjem

9_ The powerhouse shaft with generator

Insulated System) tehnologiji in predstavlja enega od vozlišč 110 kV severno primorske zanke. Stikališče je opremljeno z dvosistemskimi zbiralkami, sistemom lokalnega vodenja in zaščito. Stikališče je daljinsko vodeno iz nadrejenega centra vodenja. Ob 110 kV stikališču je nameščen mrežni transformator z močjo 200 MVA, ki povezuje motor/generator s 110 kV omrežjem. To je trenutno največji transformator, izdelan v Sloveniji. Vzbujalni sistem je specifični element v ČHE Avče in omogoča spremembo vrtljajev na agregatu (varspeed). Srce vzbujalnega sistema je trinivojski VSI (Voltage Source Inverter) pretvorniški sistem. Sestavljen je iz usmerniškega in razsmerniškega dela, ki ju povezuje enosmerni tokokrog. Glavni sestavni deli vzbujalnega sistema so IGCT (Integrated Gatecommutated Thyristor) tristorji, ki so trenutno ena od naprednejših izvedb močnostnih polprevodnikov. Vzbujalni sistem rotorju generatorja spreminja napetost, frekvenco in slip. S temi parametri dobi agregat široko področje delovanja. V vzbujalnem sistemu je že integrirano krmiljenje in zaščita samega sistema.

premises for other electrical equipment (transformers, switchgear, generator circuit breaker, diesel generator ...). In the powerhouse basement, situated at the height of 113.00 m power distribution units, oil reservoirs, accumulators and auxiliary storages are located.

The power plant is connected to the electricity power network across the 110 kV switchgear and main transformer. The 110 kV switchgear is made in the GIS (Gas Insulated System) technology and belongs to one of the 110 kV junctions of the Northern Primorska loop. The switchgear is equipped with the double busbars, local control system and protection. It is controlled from the superior remote control centre. Beside the 110 kV switchgear the mains supply transformer is installed with the power of 200 MVA, connecting motor/generator with the 110 kV network. At the moment, this transformer is the largest one ever made in Slovenia. The excitation system is one of the specific elements, used in the Pumped-Storage Hydro Power Plant Avče, enabling the rotation speed variability on the aggregate. The excitation system's heart is the three-level VSI (Voltage Source Inverter). It consists of the inverter and the converter part, connected by the one-way circuit. The main component parts of the excitation system are IGCT (Integrated Gatecommutated Thyristors), presenting one of the most advanced realisations of the power semiconductors at the moment. The excitation system changes



10_ Podolžni profil celotne naprave

10 _ Facility cross-section

Vtočno-iztočni objekt

Povezava akumulacijskega bazena Ajba s turbinskim traktom v strojnici je izvedena preko vtočno-iztočnega kanala, spodnjega iztoka, odvodnega jaška in odvodnega tunela, ki je priključen na turbinski sifon. V spodnjem iztoku so nameščeni zapornica s hidravličnim pogonom, ki ločuje elektrarno od akumulacijskega bazena Ajba, spodnja vtočna rešetka, ki preprečuje vstop večjih plavajočih predmetov v vtočni kanal, in čistilni stroj, ki je namenjen čiščenju vtočnih rešetk spodnjega vtoka. Spodnji iztok je z vodnim bazenom povezan s kanalom dolžine 40 m, ki deluje kot iztočni kanal, ko je elektrarna v generatorskem obratovalnem režimu, in kot vtočni kanal, ko je elektrarna v črpalnem obratovalnem režimu.

The Inlet-Outlet Building

The connection of the water-storage reservoir Ajba with the powerhouse turbine tract is carried out across the inlet-outlet building and tailrace shaft, connected to the turbine siphon. In the lower intake the lower intake gate, separating the power plant from the water-storage reservoir Ajba is installed, as well as the lower intake trashrack, preventing the ingress of larger floating objects into the tailrace shaft and cleaning machine for the lower intake trashrack cleaning. The lower intake is connected with the water reservoir across the 40 m long channel, functioning as an outlet channel in cases, when the power plant operates in the generator operation mode and as an inlet

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11_ Zgradba strojnice ob spodnjem akumulacijskem bazenu Ajba

11_ The powerhouse structure near the lower water-storage reservoir Ajba

12

12_ Vtočno-iztočni objekt

12_ The inlet-outlet building

Spodnji bazen

Obstoječi bazen akumulacije Ajba na reki Soči je uporabljen kot spodnji bazen črpalne hidroelektrarne. Pri optimalnem obratovanju verige hidroelektrarn Doblar in Plave lahko črpalna hidroelektrarna koristi prost volumen akumulacije, ki znaša 416.000 m³.

Priključek na omrežje

Črpalna hidroelektrarna Avče je priključena na 110 kV omrežje severnoprimorske zanke preko dvojnega dvosistemskega 110 kV daljnovoda in kablovoda v skupni dolžini 1,6 km ter mrežnega transformatorja moči 200 MVA.

–

channel in cases, when the power plant operates in the pump operation mode.

The Lower Reservoir

The existing Water-Storage Reservoir Ajba on the Soča River is used as a lower reservoir of the pumped-storage hydro power plant. In cases of the Doblar and Plave Hydro Power Stations Chain's optimal operation the pumped-storage hydro power plant can use the free accumulation volume, amounting to 416,000 m³.

The Network Connection

The Pumped-Storage Hydro Power Plant Avče is connected to the 110 kV network of the Northern Primorska loop across the double dual-system 110 kV transmission line and cable in the total length of 1.6 km and the network transformer with the power of 200 MVA.

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Tehnološka oprema elektrarne
The Power Plant's Technological Equipment

Pri snovanju nove črpalne hidroelektrarne je bila sprejeta odločitev o namestitvi enega agregata, ki reverzibilno deluje kot turbina in črpalka. Z dodatno odločitvijo o uporabi agregata s spremenljivo hitrostjo delovanja je dobila tehnološka oprema nove hidroelektrarne vrsto dodatnih prednosti. Črpalna hidroelektrarna Avče je z vidika instalirane tehnološke opreme med prvimi elektrarnami v Evropi.

Črpalka/turbina s pomožno opremo

Prednost črpalne hidroelektrarne Avče je v tem, da deluje v turbinskem in črpalnem sistemu z istim gonilnikom tipa Francis, ki je na skupni gredi spojen z motor/generatorjem. V črpalnem režimu, ko motor/generator deluje v motornem režimu, gonilnik opravlja vlogo črpalke, v generatorskem režimu pa se gonilnik obnaša kot turbina. Značilnost tega reverzibilnega delovanja agregata je tudi različna smer vrtenja v različnih režimih delovanja. Gonilnik črpalke/turbine je vgrajen v spiralno ohišje, dotok vode se na gonilnik usmerja preko fiksnih lopatic predvodilnika, vodilnik pa z 12 gibljivimi lopaticami avtomatsko regulira dotok vode glede na določen režim obratovanja, služi pa tudi kot osnovni zaporni element. Pred spiralnim ohišjem, na strani tlačnega cevovoda, je kot pomožni zaporni element vgrajen še kroglasti zasun.

Motor/generator s sistemom vzbujanja

Motor/generator je dvojno napajan asinhronski stroj (DFIM – Doubly Fed Induction Machine) s spremenljivo hitrostjo vrtenja. Vrtljaji se spreminjajo s pomočjo tiristorskega vzbujalnega sistema v ICGT (Integrated Gatecommutated Thyristor) tehnologiji. Prednost navedene tehnologije je zlasti v boljšem izkoristku, saj se lahko s tovrstnim stro-

When the new pumped-storage hydro power plant was planned, it was decided that it should contain one aggregate with the reversible pump/turbine operation. With the additional decision to use the aggregate with a variable operation rate the technological equipment of the new hydro power station gained a whole set of additional advantages. Thus, as far as the installed technological equipment is concerned, the Pumped-Storage Hydro Power Plant Avče stands among the first power plants in Europe.

The Pump/Turbine with the Additional Equipment

The advantage of the Pumped-Storage Hydro Power Plant Avče lies in the fact that it operates both in turbine and pump operation modes with the same Francis type runner, connected with the motor/generator on the common shaft. In the pump operation mode, when the motor/generator operates in the motor operating mode, the runner plays the role of the pump, whereas in the generator operation mode it takes over the role of the turbine. The main characteristics of the aggregate reversible mode of operation are also different rotation directions in different modes of operation. The pump/turbine runner is installed into the spiral housing, the water flow is directed towards the runner across the fixed stay ring blade bones, whereas the runner automatically regulates the water flow according to the chosen operation mode by means of the 12 flexible blade bones and is used as the main shut-off element as well. In front of the spiral housing, at the pressure penstock side the main inlet valve is also installed as an auxiliary shut-off element.

The Motor/Generator with the Excitation System

The motor/generator is a DFIM (Doubly Fed Induction Machine) with the variable rotation speed. The revolutions are changing by means of the ICGT (Integrated Gatecommutated Thyristor) technology. This technology's advantage lies above all in a better utilisation rate, as this machine offers the possibility of adjustment to the desired power and its drop, slightly oscillating according to the reservoir fullness, which actually enables the facility's highest utilisation rate. The other advantages of this technology are quick response, synchronisation and power regulation in the pump operation mode.


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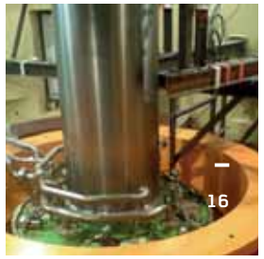
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13_ Vzbujalni sistem
13_ Excitation system

14_ 110 kV stikališče
14_ 110 kV switchgear

15_ 110 kV daljnovod
15_ 110 kV transmission line

16_ Turbinska gred z regulacijskim obročem
16_ Turbine shaft with regulation loop

jem prilagajamo želeni moči in padcu, ki glede na napolnjenost bazena nekoliko niha, tako da je izkoristek največji. Prednosti so še v hitri odzivnosti, sinhronizaciji in regulaciji moči v črpalnem režimu.

Tehnične karakteristike

Koristni volumen vode: **Vk = 2.200.000 m³**
Maksimalni bruto padec: **Hbruto max = 521 m**
Instalirani pretok (turbinski režim): **Qi = 40 m³/s**
Instalirani pretok (črpalni režim): **Qč = 34 m³/s**
Instalirana moč turbine: **Pt = 185 MW**
Instalirana moč črpanja: **Pč = 180 MW**
Letna proizvodnja električne energije: **El = 426 GWh**
Letna poraba energije za črpanje: **Eč = 553 GWh**

Technical Characteristics

Effective storage capacity: **Vk = 2,200,000 m³**
Max. gross head: **Hgross max = 521 m**
Max. discharge (turbine operation): **Qi = 40 m³/s**
Max. discharge (pumped operation): **Qp = 34 m³/s**
Installed capacity in turbine operation: **Pt = 185 MW**
Installed capacity in pump operation: **Pp = 180 MW**
Annual average energy production: **Ep = 426 GWh**
Annual average energy consumption: **Ec = 553 GWh**

Projekt nove elektrarne so uresničili
The New Power Plant Project was realised by

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Investor:

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Nova Gorica, Slovenija

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