PRIMJENA LINIJSKIH ODVODNIKA PRENAPONA ZA ZAŠTITU DALEKOVODA 110 kV STON - KOMOLAC OD ATMOSFERSKIH PRAŽNJENJA

APPLICATION OF LINE SURGE ARRESTERS IN THE PROTECTION OF THE 110 kV STON - KOMOLAC TRANSMISSION LINE FROM ATMOSPHERIC DISCHARGES

Miroslav Mesić – Milan Puharić – Dalibor Škarica, Zagreb, Hrvatska

Pouzdanost pogona prijenosne mreže u velikoj mjeri utječe na pouzdanost elektroenergetskog sustava i sigurnost opskrbe potrošača električnom energijom. Zbog specifičnog položaja u zoni intenzivnih atmosferskih pražnjenja DV 110 kV Ston – Komolac je u posljednjih 10 godina imao veliki broj ispada iz pogona čime su značajno smanjeni pouzdanost i sigurnost pogona tog dijela prijenosne mreže. Kao tehnički i ekonomski najpovoljnije rješenje za poboljšanje zaštite dalekovoda od atmosferskih pražnjenja odabrano je opremanje dalekovoda linijskim odvodnicima prenapona. Njihovom ugradnjom bitno su smanjeni broj i trajanje prekida pogona predmetnog dalekovoda radi prisilnih zastoja te povećana pouzdanost prijenosne mreže na širem dubrovačkom području. Opremanje dalekovoda linijskim odvodnicima prenapona predstavlja temelj za pilot projekt monitoringa pogona dalekovoda za vrijeme atmosferskih pražnjenja. Iskustva i rezultati učinkovitosti primijenjene zaštite DV 110 kV Ston – Komolac od atmosferskih pražnjenja bit će podloga za daljnje primjene i na dalekovode viših naponskih razina.

The reliability of the operation of a transmission network largely influences the reliability of the power system and the security of the electricity supply to consumers. During the past 10 years, there have been a large number of outages of the 110 kV Ston – Komolac Transmission Line due to its specific location in a zone where the intensity of atmospheric discharge is high, which has thereby significantly reduced the reliability and security of the operation of that section of the transmission network. As the most technically and economically desirable solution for improving the protection of the transmission line from atmospheric discharges, it was decided to equip the transmission line with line surge arresters. Their installation significantly reduced the number and duration of forced outages and increased the reliability of the transmission network in the greater Dubrovnik region. Equipping the transmission line with line surge arresters was the basis for a pilot project of monitoring the operation of the transmission line during atmospheric discharges. The experiences and results regarding the efficiency of the protection of the 110 kV Ston – Komolac Transmission Line from atmospheric discharges will provide the basis for further applications on transmission lines of higher voltage levels.

Ključne riječi: atmosfersko pražnjenje; dalekovod; linijski odvodnik prenapona; pouzdanost; prijenosna mreža; prisilni zastoj
Key words: atmospheric discharge; forced outage; line surge arrester; reliability; transmission line; transmission network

https://doi.org/10.37798/2008574330

1 UVOD

Prijenosna mreža zauzima središnje mjesto u elektroenergetskom sustavu i u tehnološkom lancu opskrbe potrošača električnom energijom.
Osnovni elementi prijenosne mreže su visokonaponski dalekovodi i transformatorske stanice i o pouzdanosti njihovog pogona bitno ovise pouzdanost elektroenergetskog sustava i sigurnost opskrbe potrošača električnom energijom.
Pokazatelji pouzdanosti pogona dalekovoda broj su i trajanje prekida pogona do kojih može doći zbog različitih razloga.

Statistikom pogonskih događaja u prijenosnoj mreži [1] koja se vodi od 1995. godine zabilježen je neuobičajeno veliki broj prisilnih zastoja dalekovoda 110 kV Ston – Komolac, koji su za posljedicu imali smanjenu pouzdanost pogona tog dijela prijenosne mreže i sigurnosti napajanja šireg dubrovačkog područja električnom energijom.

Glavni razlog povećanog broja prisilnih zastoja DV 110 kV Ston – Komolac djelovanje je atmosferskih pražnjenja koja su na ovome području među najintenzivnijim u Hrvatskoj. Od nekoliko razmatranih mogućnosti za poboljšanje zaštite predmetnog dalekovoda od atmosferskih pražnjenja najprikladnijom je ocijenjena opcija ugradnje linijskih odvodnika prenapona, za koju su provedene potrebne analize i proračuni [2] i [3].

Nakon ugradnje linijskih odvodnika zabilježen je znatno manji broj i trajanje prekida pogona dalekovoda 110 kV Ston – Komolac čime je povećana pouzdanost prijenosne mreže i sigurnost opskrbe električnom energijom na tom području.
Opremanjem DV 110 kV Ston – Komolac linijskim odvodnicima prenapona i brojačima prorade odvodnika postignut je osnovni cilj – povećanje pouzdanosti pogona.

Za precizniju ocjenu primjene zaštite dalekovoda od atmosferskih pražnjenja u područjima visoke izokerauničke razine potrebni su podaci o stvarnim vrijednostima i obliku struje groma. Stoga se u nastavku pokrenuo pilot projekt opremanja dalekovoda DV 110 kV Ston – Komolac mjernim uređajima za snimanje oblika struja groma i daljinski prijenos podataka u informatički sustav korisnika u realnom vremenu.

Na temelju rezultata i primjene linijskih odvodnika prenapona za zaštitu DV 110 kV

1 INTRODUCTION

A transmission network occupies a central place in an electrical power system and the technological chain of supplying electricity to consumers.
The basic elements of a transmission network are high voltage transmission lines and substations. The reliability of their operation significantly influences the reliability of the electrical power system and the security of the electricity supply to consumers.
The indices of the reliability of the operation of a transmission line are the number and duration of outages, which can occur for various reasons.

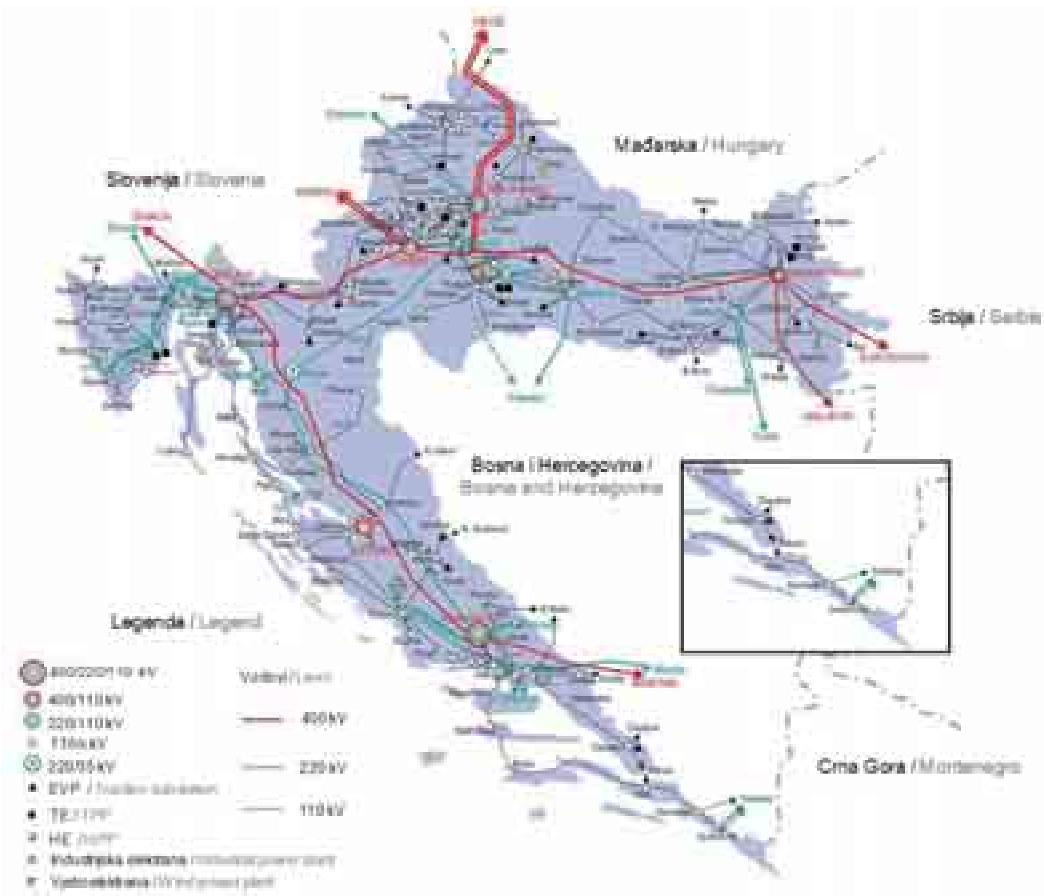
Statistics on operational events in the transmission network [1] since 1995 have recorded an unusually large number of forced outages of the 110 kV Ston – Komolac Transmission Line, resulting in a reduction in the reliability of the operation of that part of the transmission line and the security of the electricity supply of the greater Dubrovnik region.

The main reason for the increased number of forced outages of the 110 kV Ston – Komolac Transmission Line is the activity of atmospheric discharges in this region, among the most intense in Croatia. Among the several options considered for improving the protection of this transmission line from atmospheric discharges, it was decided that the most suitable was the option of installing line surge arresters, for which the necessary analyses and calculations were performed, [2] and [3].

Following the installation of the line surge arresters, significantly fewer and shorter outages were recorded in the operation of the 110 kV Ston – Komolac Transmission Line, thereby increasing the reliability of the transmission network and the security of the electricity supply in this region.
By equipping the 110 kV Ston – Komolac Transmission Line with line surge arresters and surge counters, the main goal was achieved, i.e. increased reliability of operation.

In order to provide a precise assessment of the achieved degree of protection of the transmission line from atmospheric discharges in regions of high isokeraunic levels, the actual lightning current parameters are required. Therefore, another pilot project was inaugurated to equip the 110 kV Ston – Komolac Transmission Line with measuring devices for recording current waveforms and transmitting data to the remote computer system of the user in real time.

Based upon the results of the application of line surge arresters for the protection of the 110 kV Ston – Komolac Transmission Line from atmospheric discharges and the investigation conducted during the pilot project, a conclusion will be reached on the



Slika 1 – Shema hrvatskog elektroenergetskog sustava
Figure 1 – The Croatian electrical power system

Ston – Komolac od atmosferskih prenapona i istraživanja navedenog pilot projekta, donijet će se zaključak o primjeni linijskih odvodnika prenapona za zaštitu od atmosferskih pražnjenja i za dalekovode 220 kV i 400 kV prijenosne mreže u područjima intenzivne izokerauničke zone.

2 ANALIZA POUZDANOSTI POGONA DV 110 kV STON KOMOLAC

Dalekovod 110 kV Ston – Komolac ima važnu ulogu u prijenosnoj mreži, jer povezuje južni dio elektroenergetskog sustava i šire dubrovačko područje s ostalim dijelom sustava (slika 1).

Pouzdanost i sigurnost pogona DV 110 kV Ston – Komolac glavni su preduvjet sigurnog plasmana električne energije proizvedene u HE Dubrovnik u elektroenergetski sustav, te napajanja električnom energijom šireg

application of line surge arresters for the protection of the 220 kV and 400 kV transmission lines of the transmission network in regions of high isokeraunic activity from atmospheric discharges.

2 ANALYSIS OF THE RELIABILITY OF THE OPERATION OF THE 110 kV STON - KOMOLAC TRANSMISSION LINE

The 110 kV Ston – Komolac Transmission Line has an important role in the transmission network because it connects the southern part of the electrical power system and the greater Dubrovnik region with the other part of the system (Figure 1).

The reliability and security of the operation of the 110 kV Ston – Komolac Transmission Line are the chief prerequisites for the secure delivery of the electrical energy generated at the Dubrovnik Hydroelectric Power Plant to the electrical power system and the supply dubrovačkog područja priključenog na TS 110/35 kV Komolac.

Kvarovi i ispadi predmetnog dalekovoda dovode do poremećaja pogona elektroenergetskog sustava i prekida opskrbe električnom energijom dubrovačkog područja, osobito osjetljivog na prekide opskrbe za vrijeme turističke sezone.

Osnovni tehnički podaci DV 110 kV Ston – Komolac (prije rekonstrukcije):

– godina izgradnje 1961.,
– duljina 43 959 m,
– broj stupova 144,
– vrsta stupova čelično-rešetkasti,
– vodiči Al/Če 150/25 mm^2,
– zaštitno uže Če 50 mm^2,
– izolatori porculan.

Tijekom 1994. godine radi povećanja prijenosne moći dalekovoda nužnog za plasman proizvodnje HE Dubrovnik u elektroenergetski sustav i povećanja pouzdanosti i sigurnosti pogona izvršena je njegova rekonstrukcija.

Rekonstrukcija dalekovoda obuhvatila je zamjenu vodiča, zaštitnog užeta i izolatora:
– godina rekonstrukcije 1994.,
– vodiči BTAL/Stalum 154/15 mm^2,
– zaštitno uže Stalum 50 mm^2,
– izolatori staklo.

of electricity to the greater Dubrovnik region, which is connected to the 110/35 kV Komolac Substation.

Failures and outages of this transmission line lead to disturbances in the operation of the electrical power system and interruption in the supply of electricity to the Dubrovnik region, which is particularly sensitive to interruptions in supply during the tourism season.

The basic technical characteristics of the 110 kV Ston – Komolac Transmission System (prior to reconstruction) were as follows:

– year of construction: 1961,
– length 43 959 m,
– number towers 144,
– type of towers steel,
– conductors aluminum/steel 150/25 mm^2,
– ground wire steel, 50 mm^2,
– insulators porcelain.

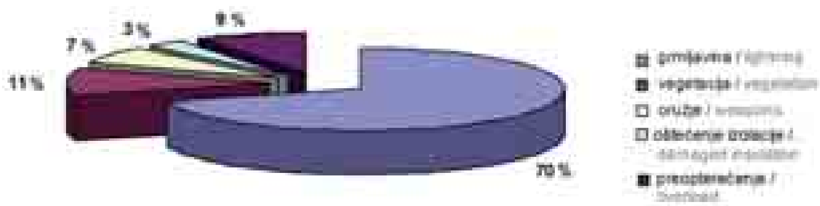
During the year 1994, in order to increase the transmission capacity of the transmission line necessary for the delivery of the electrical energy generated by the Dubrovnik Hydroelectric Power Plant to the electrical power system and increasing the reliability and security of operation, it was reconstructed.

The reconstruction of the transmission line included the replacement of conductors, ground wire and insulation:
– year of reconstruction 1994,
– conductors BTAL/ACS 154/15 mm^2 (extra thermal resistant aluminum alloy/ aluminium clad steel),
– ground wire ACS 50 mm^2,
– insulators glass.

For the necessary communication between the information system of the Croatian Electrical Power Supply Company (HEP) and the process informatics

Tablica 1 – Broj i trajanje prekida pogona DV 110 kV Ston – Komolac u razdoblju 1995. do 2006.
Table 1 – The number and duration of the outages of the 110 kV Ston – Komolac Transmission Line during the period from 1995 to 2006

Godina / Year	Godišnji broj prekida pogona / Annual number of outages	Trajanje prekida pogona / Duration of outages [h/god.] / [h/year]
1995.	23	8,23
1996.	25	5,58
1997.	24	7,95
1998.	21	6,16
1999.	30	9,56
2000.	14	4,76
2001.	13	57,48
2002.	24	2,53
2003.	12	3,46
2004.	14	18,38
2005.	18	5,26
2006.	17	1,45
Srednja vrijednost / Mean value	19,5	10,81



Slika 2 – Najčešći uzroci ispada dalekovoda iz pogona
Figure 2 – Most frequent causes of transmission line outages

Radi potrebe komunikacijskog povezivanja informatičkog sustava Hrvatske elektroprivrede i procesne informatike elektroenergetskog sustava klasično zaštitno uže zamijenjeno je 2007. godine novim zaštitnim užetom s optičkim nitima (OPGW).

Za analizu pouzdanosti pogona DV 110 kV Ston – Komolac uz navedene tehničke podatke bitni su i podaci o trasi dalekovoda:

– trasa je u blizini mora i nalazi se u specifičnim klimatskim uvjetima,
– trasa prolazi većinom brdovitim terenom,
– trasa je smještena u području jake i intenzivne izokerauničke zone.

U tablici 1 prikazani su podaci o broju i trajanju prekida pogona DV 110 kV Ston – Komolac u razdoblju 1995. do 2006. godine.

Podaci o broju i trajanju prekida pogona DV 110 kV Ston – Komolac prikazani u tablici 1 pokazuju izrazito veliki broj prekida pogona i dugo trajanje prekida pogona u razdoblju od 1995. do 2006. godine, što najbolje ilustriraju i srednje vrijednosti za razmatrano razdoblje.

Prema [2] na ispade dalekovoda iz pogona utječe nekoliko razloga od kojih najveći udjel ima djelovanje atmosferskih pražnjenja (slika 2).

S obzirom na smještaj trase dalekovoda u području jakog i intenzivnog djelovanja atmosferskih pražnjenja i najvećeg broja grmljavinskih dana u godini u Hrvatskoj (70 dana), broj prekida pogona razmatranog dalekovoda bitno je veći u odnosu na broj prekida pogona u hrvatskoj prijenosnoj mreži.

U tablici 2 prikazana je usporedba vrijednosti učestalosti prisilnih zastoja i srednjeg trajanja prekida radi prisilnih zastoja dalekovoda u prijenosnoj mreži Hrvatske i dalekovoda 110 kV Ston – Komolac za razdoblje 2002. do 2006. godine.

Vrijednosti učestalosti prisilnih zastoja i srednjeg trajanja prisilnih zastoja dalekovoda izračunati su prema izrazima:

of the electrical power system, standard ground wire was replaced in the year 2007 with new composite ground wire with optical fiber (OPGW).

For the analysis of the reliability of the operation of the 110 kV Ston – Komolac Transmission Line, in addition to the aforementioned technical data, data on the transmission line route are essential:

– the route is near the sea and subject to specific climatic conditions,
– the route passes primarily through mountainous terrain,
– the route is located in a region characterized by a high isokeraunic level.

Table 1 presents data on the number and duration of the outages of the 110 kV Ston – Komolac Transmission Line during the period from 1995 to 2006.

Data on the number and duration of the outages of the 110 kV Ston – Komolac Transmission Line presented in Table 1 show the large number and long duration of the outages during the period from 1995 to 2006, as best illustrated by the mean values for the period studied.

According to Ref. [2], several factors influence transmission line outages, of which atmospheric discharges have the greatest share (Figure 2).

Since the transmission line is located in a region of strong and intense atmospheric discharge activity with the largest number of thunder days per year in Croatia (70 days), the number of outages of the transmission line studied is significantly greater in comparison to the number of outages in the Croatian transmission network as a whole.

Table 2 presents a comparison of the values of the rate of forced outages and the mean duration of outages due to forced outages in the transmission lines of the transmission network of Croatia and the 110 kV Ston – Komolac Transmission Line for the period from 2002 too 2006.

The values of the rate of the forced outages and the mean duration of the forced outages are calculated according to the following expressions:

$$f_{PZI} = \frac{N_{PZI}}{l_{DVM}} \left[\frac{1}{\text{km} \cdot \text{god.}}\right] \quad (1)$$

gdje su:

N_{PZI} – ukupni broj prisilnih zastoja dalekovoda 110 kV,

l_{DVM} – ukupna duljina dalekovoda 110 kV,

where:

N_{PZI} – the total number of forced outages of the 110 kV line,

l_{DVM} – the total length of the 110 kV transmission line,

$$f_{PZII} = \frac{N_{PZII}}{l_{DVSK}} \left[\frac{1}{\text{km} \cdot \text{god.}}\right], \quad (2)$$

gdje su:

N_{PZII} – ukupni broj prisilnih zastoja DV 110 kV Ston – Komolac,

l_{DVSK} – duljina DV 110 kV Ston – Komolac,

where:

N_{PZII} – the total number of the forced outages of the 110 kV Ston – Komolac Transmission Line,

l_{DVSK} – the length of the 110 kV Ston – Komolac

$$T_{SRI} = \frac{T_{UI}}{l_{DVM}} [\text{h}] \quad (3)$$

gdje je:

T_{UII} – ukupno trajanje prisilnih zastoja svih dalekovoda 110 kV u Hrvatskoj.

where:

T_{UII} – the total duration of the forced outages of all the 110 kV transmission lines in Croatia.

Tablica 2 – Usporedba učestalosti i srednjeg trajanja prisilnih zastoja dalekovoda 110 kV prijenosne mreže Hrvatske i DV 110 kV Ston – Komolac

Table 2 – Comparison of the rate and mean duration of the forced transmission line outages of the 110 kV Croatian transmission network and the 110 kV Ston – Komolac Transmission Line

Godina / Year	f_{PZ} [1 / km·god.] / [1/ km·year]		T_{SR} [h]		Omjer / Ratio	
	f_{PZI}	f_{PZII}	T_{SRI}	T_{SRII}	f_{PZII} / f_{PZI}	T_{SRII} / T_{SRI}
2002.	0,069	0,54	3,7	0,105	7,82	0,028
2003.	0,085	0,27	10,1	0,288	3,17	0,028
2004.	0,076	0,32	8,3	1,310	4,21	0,157
2005.	0,065	0,41	4,4	0,292	6,30	0,066
2006.	0,072	0,39	2,6	0,085	5,41	0,032
Srednja vrijednost / Mean value	0,073	0,39	5,8	0,412	5,28	0,071

f_{PZI} – učestalost prisilnih zastoja dalekovoda 110 kV / rate of forced 110 kV Croatian transmission line outages

f_{PZII} – učestalost prisilnih zastoja DV 110 kV Ston – Komolac / rate of forced outages of the 110 kV Ston – Komolac Transmission Line

T_{SRI} – srednje trajanje prisilnih zastoja 110 kV dalekovoda u Hrvatskoj / mean duration of the forced 110 kV Croatian transmission line outages

T_{SRII} - srednja vrijednost prisilnih zastoja dalekovoda 110 kV Ston - Komolac / mean duration of the forced outages of the 110 kV Ston – Komolac Transmission Line

$$T_{SRII} = \frac{T_{UII}}{l_{DVSK}} \; [h] \quad (4)$$

gdje je:

T_{UII} – ukupno trajanje prisilnih zastoja DV 110 kV Ston - Komolac.

Iz tablice 2 je vidljivo da je u razdoblju od 2002. do 2006. godine učestalost prisilnih zastoja DV 110 kV Ston - Komolac višestruko veća od prosječne učestalosti zastoja dalekovoda 110 kV prijenosne mreže.

Također je vidljivo da je srednja vrijednost trajanja prisilnih zastoja DV 110 kV Ston - Komolac višestruko manja od srednje vrijednosti trajanja prisilnih zastoja dalekovoda 110 kV prijenosne mreže.

Izražena učestalost i relativno kratko trajanje prisilnih zastoja su glavne značajke prisilnih zastoja dalekovoda koji nastaju radi atmosferskih pražnjenja.

Podaci o prisilnim zastojima u tablici 1 i u tablici 2, značajke prisilnih zastoja te činjenica da je trasa DV 110 kV Ston - Komolac smještena u jakoj i intenzivnoj izokerauničkoj zoni pokazuju da atmosferska pražnjenja negativno utječu na pouzdanost pogona predmetnog dalekovoda i pripadajućeg dijela elektroenergetskog sustava.

3 UGRADNJA LINIJSKIH ODVODNIKA PRENAPONA

Podaci o pouzdanosti pogona DV 110 kV Ston - Komolac u razdoblju od 1995. do 2006. godine te pretpostavka kako su najčešći uzrok prisilnih zastoja atmosferska pražnjenja, upućuju na zaključak da postojeća zaštita predmetnog dalekovoda od atmosferskih pražnjenja pomoću zaštitnog užeta nije dovoljna.

Zbog povećanja pouzdanosti pogona stoga je DV 110 kV Ston - Komolac bilo nužno dodatno zaštititi od atmosferskih pražnjenja. Dodatnu zaštitu DV 110 kV Ston - Komolac moguće je ostvariti primjenom nekoliko tehničkih mogućnosti:

- pojačanje izolacije,
- ugradnja dodatnog zaštitnog užeta,
- poboljšanje otpora uzemljenja,
- ugradnja linijskih odvodnika prenapona.

where:

T_{UII} – the total duration of the forced outages of the 110 kV Ston - Komolac Transmission Line.

From Table 2, it is evident that during the period from 2002 to 2006, the rate of the forced outages of the 110 kV Ston – Komolac Transmission Line was several times greater than the average transmission line outages of the 110 kV Croatian transmission network.

Furthermore, it is evident that the mean value of the duration of the forced outages of the 110 kV Ston – Komolac Transmission Line is several times lower than the mean value of the duration of the forced transmission line outages of the 110 kV Croatian transmission network.

The marked rate and relatively brief duration of the forced outages are the main characteristics of the forced transmission line outages that occur due to atmospheric discharges.

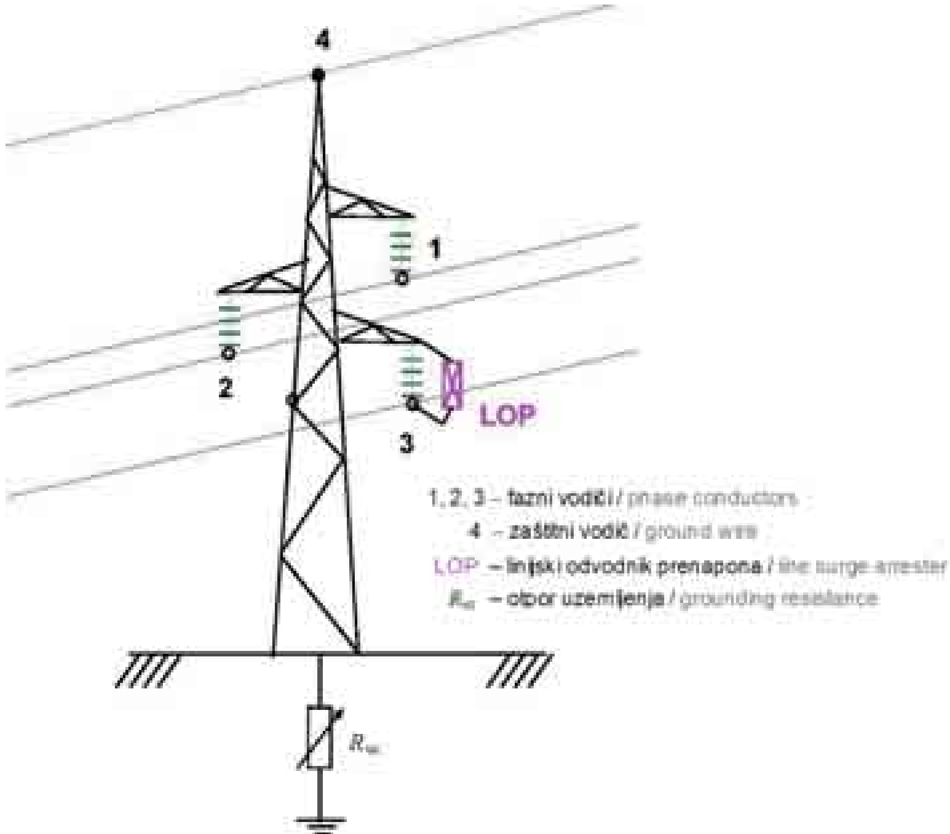
Data on forced outages in Tables 1 and 2, the characteristics of forced outages and the fact that the route of the 110 kV Ston – Komolac Transmission Line is located in a zone with a high isokeraunic level indicate that atmospheric discharges have a negative impact on the reliability of the operation of this transmission line and the corresponding part of the electrical power system.

3 INSTALLATION OF LINE SURGE ARRESTERS

Data on the reliability of the operation of the 110 kV Ston – Komolac Transmission Line during the period from 1995 to 2006 and the hypothesis that the most frequent cause of forced outage is atmospheric discharge led to the conclusion that the existing protection of the transmission line from atmospheric discharges using ground wire had been inadequate.

In order to increase the reliability of the 110 kV Ston – Komolac Transmission Line, it was necessary to provide additional protection from atmospheric discharges. There were several technical options for providing additional protection of the 110 kV Ston – Komolac Transmission Line:

- strengthening insulation,
- installing additional ground wire,
- reducing grounding resistance,
- installing line surge arresters.



Slika 3 – Mjesto ugradnje linijskog odvodnika prenapona na stupu dalekovoda
Figure 3 – Line surge arrester installed on a transmission line tower

Tehnički i ekonomski i posebice u odnosu na zahtijevanu brzinu izvođenja zahvata uvjetovanu ograničenim vremenom isključenja dalekovoda iz pogona, najpovoljnija je opcija ugradnja linijskih odvodnika prenapona. Linijski odvodnik prenapona ugrađuje se između faznog vodiča i čelične konstrukcije stupa dalekovoda, poštujući pritom dopuštenu udaljenost vodiča pod naponom i spoja odvodnika na uzemljenu čeličnu konstrukciju stupa (slika 3).

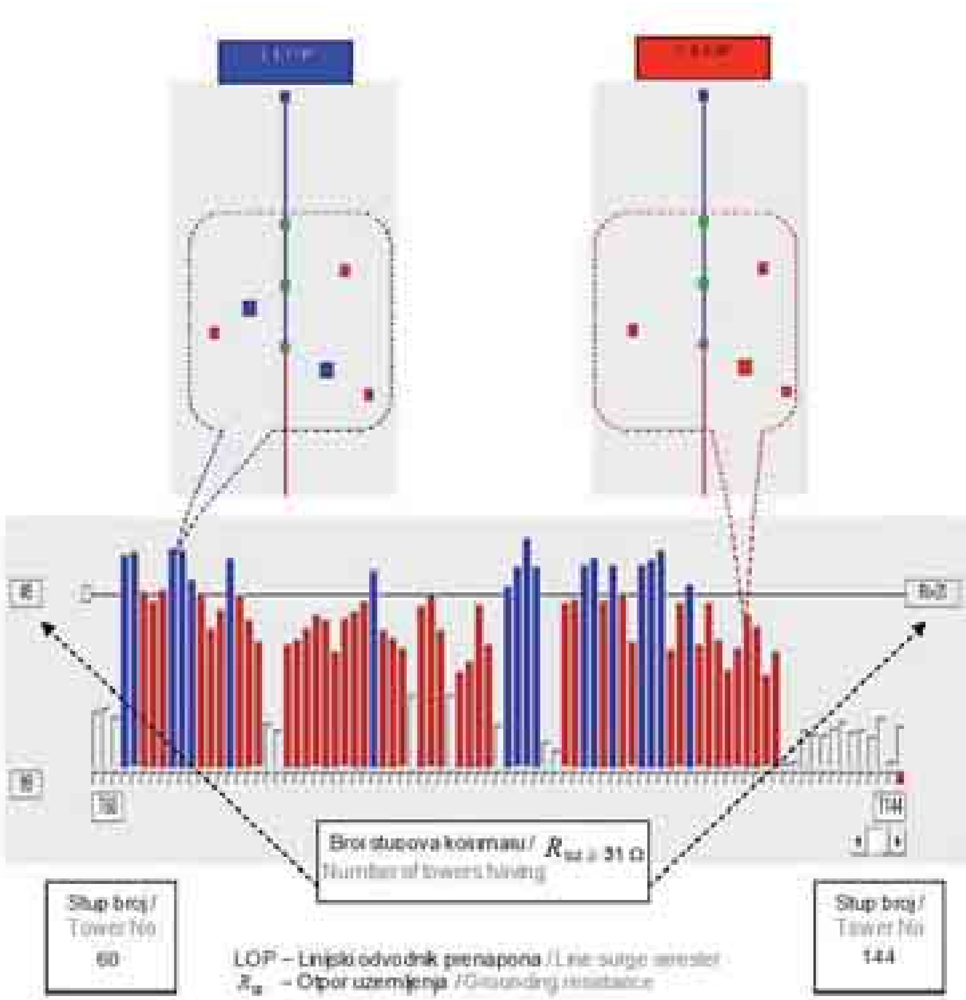
Odabir stupova dalekovoda na koje će se ugraditi odvodnici, odabir broja odvodnika po stupu (1 ili 2), te mjesta ugradnje po fazama prema [3] određen je posebnim računalnim programom [2] koji za različite otpore uzemljenja stupova određuje najpovoljniji broj i raspored odvodnika prenapona.

Za konačnu odluku o odabiru mjesta ugradnje i kombinacije odvodnika po fazama uz rezultate navedenog računalnog programa uzima se u obzir analiza prisilnih zastoja dalekovoda u prošlom razdoblju te raspoloživi meteorološki podaci.

From the technical and economic points of view, particularly regarding the time required for the implementation of the undertaking due to the limited acceptable downtime for the transmission line, the optimal choice was the installation of line surge arresters. Each line surge arrester was installed between the phase conductor and the steel tower structure of a transmission line, complying with the permitted distance between the live conductor and the connection point of the surge arrester to the grounded steel tower structure (Figure 3).

The selection of the transmission line towers on which the surge arresters were installed, the determination of the number of arresters per tower (1 or 2) and the site of installation according to phases as specified in Reference [3] were established by a special software program, [2], which determines the optimal number and distribution of surge arresters for various tower footing resistances.

For the final decision on the choice of the installation site and the combination of arresters according to phases, together with the results of the aforementioned software program, analysis of the forced outages of the transmission line during the previous period and the available meteorological data were taken into account.



Slika 4 – Primjer konfiguracije odvodnika prenapona za zaštitu DV 110 kV Ston - Komolac od atmosferskih pražnjenja (dionica od stupa 60 - 144)

Figure 4 – Example of a configuration of surge arresters for the protection of the 110 kV Ston - Komolac Transmission Line from atmospheric discharges (The section between Towers 60 - 144)

Na taj način utvrđena je i konfiguracija linijskih odvodnika prenapona za zaštitu DV 110 kV Ston - Komolac od atmosferskih pražnjenja (slika 4).

Ugradnja linijskih odvodnika prenapona i brojača za registraciju prorada odvodnika i struja odvoda na DV 110 kV Ston - Komolac obavljena je u ljeto 2007. godine u trajanju od 2 tjedna, a obuhvatila je:

– ukupni broj linijskih odvodnika prenapona 110,
– broj stupova s odvodnicima 86,
– broj stupova s odvodnikom u

In this manner, the configuration of the line surge arresters for the protection of the 110 kV Ston – Komolac Transmission Line from atmospheric discharges was determined (Figure 4).

The installation of line surge arresters and surge counters for the registration of the number of discharges through surge arresters and arrester discharge currents on the 110 kV Ston – Komolac Transmission Line was performed during a 2-week period in the summer of 2007, and included the following:

– total number of line surge arresters 110,
– number of towers with arresters 86,
– number of towers with an arrester in the low phase 62,

Tablica 3 - Usporedba prisilnih zastoja DV 110 kV Ston - Komolac prije i poslije ugradnje linijskih odvodnika prenapona

Table 3 - A comparison of the forced outages of the 110 kV Ston – Komolac Transmission Line before and after the installation of line surge arresters

Prisilni zastoji / Forced outages					
Prije ugradnje / Before installation			Poslije ugradnje / After installation		
2006-06-20 do / to 2007-03-31/			2007-07-20 do / to 2008-03-31 /		
Godina / Year	Mjesec/dan / Month/day	Trajanje / Duration [min]	Godina / Year	Mjesec/dan / Month/day	Trajanje / Duration [min]
2006.	08-07	4	2007.	09-19	7
	08-12	2			7
	08-25	3		10-31	38
		2		11-17	3
		4	2008.	03-24	26
	08-27	8			
	09-15	15			
	09-16	2			
	09-18	3			
	09-20	18			
	10-04	2			
2007.	01-23	4			

donjoj fazi 62,
- broj stupova s odvodnicima u donjoj i srednjoj fazi 24,
- broj brojača prorade odvodnika 49,
- broj stupova s jednim brojačem 21,
- broj stupova s dva brojača 14.

Osnovni tehnički podaci polimernih metaloksidnih linijskih odvodnika prenapona:

- nazivni napon 108 kV,
- maksimalni pogonski napon 86 kV,
- nominalna struja pražnjenja 10 kA,
- IEC klasa II,
- masa 30 kg,
- visina 1147 mm,
- temperaturno područje -40 °C do +50 °C.

Podaci o proradi odvodnika prenapona i struji odvoda koje registrira brojač periodički se očitavaju sa zemlje pomoću posebnog instrumenta, te pohranjuju u bazu podataka.

4 OCJENA UČINKA LINIJSKIH ODVODNIKA PRENAPONA NA POBOLJŠANJE POUZDANOSTI POGONA DV 110 kV STON - KOMOLAC

U prvoj godini pogona DV 110 kV Ston - Komolac s ugrađenim linijskim odvodnicima

- number of towers with arresters in the low and medium phases 24,
- number of arrester discharge counters 49,
- number of towers with one counter 21,
- number of towers with two counters 14.

The basic technical data on metal oxide line surge arresters with polymer housing are as follows:

- nominal voltage 108 kV,
- maximum continuous operating voltage 86 kV,
- nominal discharge current 10 kA,
- IEC class II,
- mass 30 kg,
- height 1147 mm,
- temperature range -40° C to +50° C.

Data on the surge arrester currents and the number of discharges registered by the counters are periodically read from the ground using a special instrument and stored in a database.

4 EVALUATION OF THE IMPACT OF LINE SURGE ARRESTERS ON IMPROVING THE RELIABILITY OF THE OPERATION OF THE 110 kV STON – KOMOLAC TRANSMISSION LINE

During the first year of the operation of the 110 prenapona zabilježen je dvostruko maji broj prisilnih zastoja nego u istom razdoblju prethodne godine čime je ostvarena veća pouzdanost pogona i sigurnost opskrbe električnom energijom na širem dubrovačkom području.

Usporedba prisilnih zastoja prije i poslije ugradnje odvodnika opisana u [4] prikazana je u tablici 3.

Analiza podataka prikupljenih brojačem prorada pokazuje značajnu aktivnost odvodnika i dokazuje visoku izokerauničku razinu područja kojim prolazi trasa dalekovoda, a detaljni podaci o aktivnosti odvodnika po fazama i stupovima upućuju na najugroženija mjesta u pogledu utjecaja atmosferskih pražnjenja.

Bolja ocjena učinka linijskih odvodnika prenapona na poboljšanje pouzdanosti pogona DV 110 kV Ston - Komolac moći će se dati daljim praćenjem prisilnih zastoja i analizom podataka brojača prorade.

Usporedba konfiguracije linijskih odvodnika prenapona dobijena računalnim programom i podataka o prisilnim zastojima i proradi brojača predmetnog dalekovoda može potvrditi izabranu konfiguraciju odvodnika, ili uputiti na korekcije konfiguracije – premještaj postojećih, ili ugradnju dodatnih linijskih odvodnika prenapona.

5 PILOT PROJEKT MONITORINGA POGONA LINIJSKIH ODVODNIKA PRENAPONA DV 110 kV STON - KOMOLAC

Ugradnjom linijskih odvodnika prenapona na DV 110 kV Ston - Komolac ostvaren je temeljni postavljeni cilj – smanjivanje broja i trajanja prisilnih zastoja dalekovoda i povećanje pouzdanosti pogona.

Za cjelovitu ocjenu svih učinaka zaštite dalekovoda od atmosferskih pražnjenja i primjenu na postojećim i novim dalekovodima viših naponskih razina u sličnim izokerauničkim zonama, uz stalno praćenje i analizu pogona DV 110 kV Ston - Komolac, nužna su dodatna mjerenja i snimanja oscilograma struja groma koja bi pridonijela kvaliteti simulacije atmosferskih pražnjenja i određi-

kV Ston – Komolac Transmission Line after the line surge arresters were installed, a two-fold reduction in the number of forced outages in comparison to the same period of the previous year was recorded, thereby achieving increased reliability of operation and security of the supply of electricity to the greater Dubrovnik region.

A comparison of forced outages before and after the installation of the surge arresters, described in Ref. [4], is presented in Table 3.

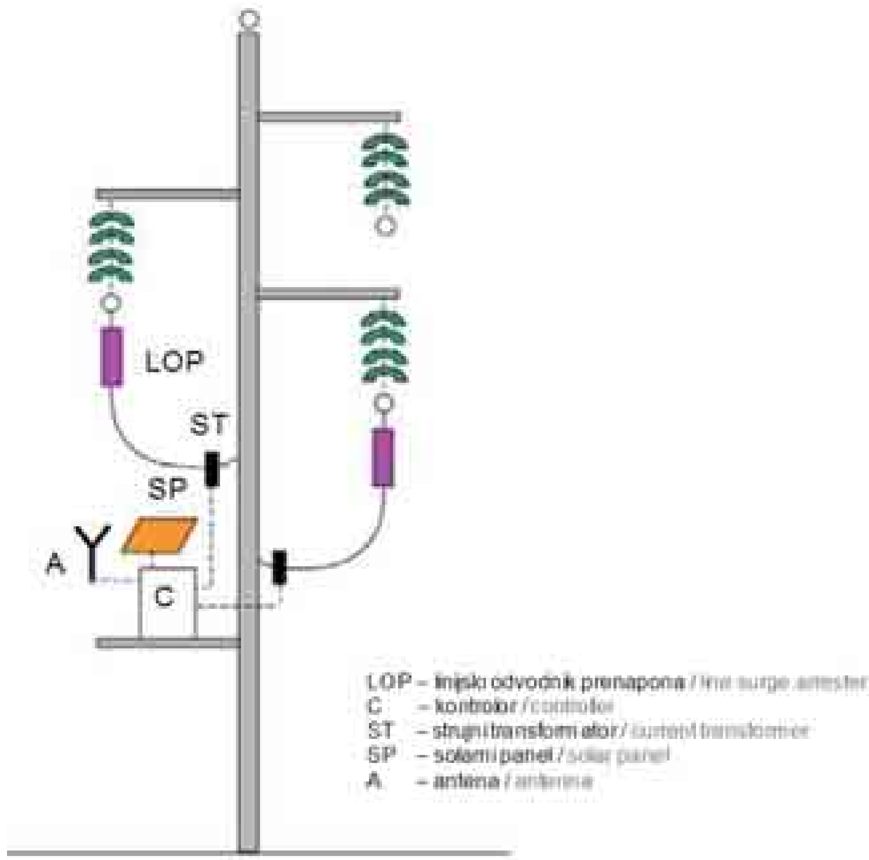
Analysis of the data collected with the surge counters indicates significant surge arrester activity and a high isokreaunic level of the region through which the transmission line passes. Detailed data on the surge arrester activity according to phases and towers indicate which places are the most vulnerable to atmospheric discharges. Further assessment of the impact of the line surge arresters on improving the reliability of the operation of the 110 kV Ston – Komolac Transmission Line will be possible after additional monitoring of the forced outages and analysis of the surge counter data.

Comparison of the configuration of the line surge arresters obtained using the software program and data on forced outages and surge counters could either confirm the selected surge arrester configuration or suggest a correction in the configuration, the relocation of existing line surge arresters or the installation of additional ones.

5 PILOT PROJECT ON MONITORING THE OPERATION OF THE LINE SURGE ARRESTERS OF THE 110 kV STON – KOMOLAC TRANSMISSION LINE

With the installation of line surge arresters on the 110 kV Ston – Komolac Transmission Line, the basic goal has been achieved, i.e. a reduction in the number and duration of the forced outages of the transmission line and an increase in the reliability of operation.

For an overall assessment of the effects of the protection of the transmission line from atmospheric discharges and the application on existing and new transmission lines of higher voltage levels in zones with similar isokeraunic levels, together with the constant monitoring and analysis of the operation of the 110 kV Ston – Komolac Transmission Line, additional measurements



Slika 5 – Monitoring pogona linijskih odvodnika prenapona
Figure 5 – Monitoring the operation of line surge arresters

vanja optimalnog broja i konfiguracije linijskih odvodnika prenapona za zaštitu dalekovoda od atmosferskih pražnjenja.

S tim ciljem pokrenut je pilot projekt monitoringa pogona linijskih odvodnika prenapona DV 110 kV Ston - Komolac koji predviđa ugradnju 2 uređaja za registraciju i oscilografiranje struje groma na mjestima gdje su zabilježena intenzivna atmosferska pražnjenja.

Oscilogrami struje groma prenosit će se do računala bežičnim komunikacijskim putem do transformatorske stanice i interne računalne mreže ili, ako bude izvedivo, direktno priključkom uređaja na optičke niti u zaštitnom užetu predmetnog dalekovodnog stupa (slika 5).

Pilot projekt predviđa prikupljanje, obradu i analizu podataka o prisilnim zastojima, broju prorada brojača, struji odvoda odvodnika i oscilograma struja groma predmetnog dalekovoda u razdoblju od dvije godine.

are necessary. Oscillograms of the lightning current could contribute to the quality simulation of the atmospheric discharges and the determination of the optimal number and configuration of line surge arresters for the protection of the transmission lines from atmospheric discharges.

With this goal, a pilot project has been launched for the monitoring of the operation of the line surge arresters on the 110 kV Ston – Komolac Transmission Line, which anticipates the installation of two devices for registering and recording lightning currents at locations where intense atmospheric discharges have been noted.

Oscillograms of lightning current will be transmitted wirelessly to a computer, substation and the internal computer network or, if feasible, via direct connection of the device to the optical fiber ground wire of the transmission line tower (Figure 5).

The pilot project anticipates the collection, processing and analysis of transmission line data on forced

Rezultati navedenih analiza i istraživanja pokazat će učinkovitost primijenjene konfiguracije linijskih odvodnika prenapona za zaštitu dalekovoda od atmosferskih pražnjenja te ukazati na potrebu premještanja postojećih i eventualnog dodavanja novih odvodnika prenapona.

Poznavanje oscilograma i značajki stvarnih struja groma bit će temelj za poboljšanja kvalitete ulaznih podataka i simulacija računalnog programa za određivanje optimalne konfiguracije linijskih odvodnika prenapona, a time i poboljšanje učinkovitosti zaštite dalekovoda od atmosferskih pražnjenja.

Na temelju rezultata pilot projekta donijet će se također i zaključak o daljoj primjeni linijskih odvodnika prenapona za zaštitu dalekovoda 110 kV, 220 kV i 400 kV od atmosferskih pražnjenja u prijenosnoj mreži Hrvatske.

6 ZAKLJUČAK

DV 110 kV Ston - Komolac osobito je značajan u prijenosnoj mreži Hrvatske radi plasmana proizvodnje električne energije HE Dubrovnik u elektroenergetski sustav, te napajanja električnom energijom šireg dubrovačkog područja.

Trasa DV 110 kV Ston - Komolac prolazi područjem intenzivne izokerauničke zone s približno 70 grmljavinskih dana u godini, te učestalim i jakim atmosferskim pražnjenjima.

Zbog toga je u pogonu tog dalekovoda u razdoblju od 1995. do 2006. godine zabilježen veliki broj i trajanje prisilnih zastoja koji su znatno veći od prosjeka u prijenosnoj mreži Hrvatske.

S ciljem zaštita od atmosferskih pražnjenja, poboljšanja pouzdanosti pogona i povećanja sigurnosti opskrbe električnom energijom dubrovačkog područja na DV 110 kV Ston - Komolac u ljeto 2007. godine ugrađeni su linijski odvodnici prenapona i brojači prorade odvodnika.

Prvi rezultati praćenja pogona pokazali su da su broj i trajanje prisilnih zastoja u odnosu na prethodno razdoblje dvostruko smanjeni čime je i postignut temeljni cilj opremanja dalekovoda linijskim odvodnicima prenapona – povećanje pouzdanosti pogona i sigurnosti opskrbe električnom energijom.

outages, the number of surges, discharge currents and oscillograms of the lightning current during a period of two years.

The results of these analyses and investigation will demonstrate the efficiency of the applied configuration of line surge arresters for the protection of the transmission line from atmospheric discharges and the eventual need for the relocation of existing line surge arresters and the addition of new ones.

The oscillograms and parameters of the actual lightning currents will provide the basis for the improvement of input data and simulation using a software program for the determination of the optimal configuration of the line surge arresters, and thereby also the improvement of the efficiency of the line transmission protection from atmospheric discharges.

Based upon the results of the pilot project, a conclusion will also be reached regarding the continued application of line surge arresters for the protection of 110 kV, 220 kV and 400 kV transmission lines from atmospheric discharges in the transmission network of Croatia.

6 CONCLUSION

The 110 kV Ston – Komolac Transmission Line is particularly significant in the transmission network of Croatia due to the delivery of energy generated by the Dubrovnik Hydroelectric Power Plant to the electrical power system and the supply of electrical energy to the greater Dubrovnik region.

The route of the 110 kV Ston – Komolac Transmission Line passes through a region that has a high isokeraunic level with approximately 70 thunder days per year and frequent strong atmospheric discharges.

Therefore, in the operation of this transmission line during the period from 1995 to 2006, a large number of forced outages of long duration were recorded, which greatly exceeded the average for the transmission network of Croatia.

With the goals of providing protection from atmospheric discharges, improving operation reliability and increasing the security of the supply of electricity to the Dubrovnik region, line surge arresters and surge counters were installed on the 110 kV Ston – Komolac Transmission Line during the summer of 2007.

The initial results of the monitoring operations

Pilot projektom monitoringa pogona linijskih odvodnika prenapona DV 110 kV Ston - Komolac u nastavku je predviđeno instaliranje 2 mjerna uređaja za mjerenje i oscilografiranje oblika struja groma na stupovima u zoni najintenzivnijih atmosferskih pražnjenja te dalje praćenje i analiza broja i trajanja prisilnih zastoja i djelovanja atmosferskih pražnjenja.

Rezultati pilot projekta bit će temelj za primjenu linijskih odvodnika prenapona za zaštitu dalekovoda od atmosferskih pražnjenja i na višim naponskim razinama.

demonstrated that the number and duration of the forced outages in relation to the previous period were reduced by two-fold, thereby achieving the basic goal of increasing the security of operation and the electricity supply by equipping the transmission line with line surge arresters.

The continuation of the pilot project for the monitoring of the operation of the line surge arresters of the 110 kV Ston – Komolac Transmission Line anticipates the installation of two devices for measuring and recording lightning current waveforms at the towers in the zone of the greatest intensity of atmospheric discharges and the continued monitoring and analysis of the number and duration of forced outages and atmospheric discharges.

The results of the pilot project will provide the basis for determining the use of line surge arresters for the protection of the transmission line from atmospheric discharges at higher voltage levels.

LITERATURA / REFERENCES

[1] Statistika pogonskih događaja u prijenosnoj mreži u 2006. godini, HEP-Operator prijenosnog sustava d.o.o., 2007.

[2] SADOVIĆ, S., Different Line Surge Arrester Application, International Colloquium Application of Line Surge Arresters in Power Distribution and Transmission Systems, Cavtat, 2008

[3] PUHARIĆ, M., MESIĆ, M., LOVRIĆ, M., RADOVANOVIĆ, J., SADOVIĆ, S., Lighting Performance Improventment of 123 kV Line Ston-Komolac by Use of Line Surge Arresters, International Colloquium Application of Line Surge Arresters in Power Distribution and Transmission Systems, Cavtat, 2008

[4] BOJIĆ, S., DOLIĆ, I., SEKSO, A., RADOVANOVIĆ,J., ŠKARICA, D., First Experience in Monitoring of Line Surge Arresters Installed on 110 kV Transmission Line Ston - Komolac in Croatia, International Colloquium on Application of Line Surge Arresters in Power Distribution and Transmission Systems, Cavtat, 2008

Adresa autora:

Miroslav Mesić, dipl. ing.
miroslav.mesic@hep.hr
Dalibor Škarica, dipl. ing.
d.skarica@hep.hr
HEP-Operator prijenosnog sustava d.o.o.
Kupska 4
10000 Zagreb
Hrvatska
Dr. sc. **Milan Puharić**
milan.puharic@hera.hr
Hrvatska energetska regulatorna agencija (HERA)
Ulica grada Vukovara 14
10000 Zagreb
Hrvatska

Address of author:

Miroslav Mesić, dipl. ing.
miroslav.mesic@hep.hr
Dalibor Škarica, dipl. ing.
d.skarica@hep.hr
HEP-Operator prijenosnog sustava d.o.o.
Kupska 4
10000 Zagreb
Croatia
Milan Puharić, PhD
milan.puharic@hera.hr
Hrvatska energetska regulatorna agencija (HERA)
Ulica grada Vukovara 14
10000 Zagreb
Croatia

Uredništvo primilo rukopis:
2008-09-22

Prihvaćeno:
2008-10-02

Manuscript received on:
2008-09-22

Accepted on:
2008-10-02