PROCJENA RIZIKA STRADAVANJA RADNIKA DISTRIBUCIJE

ASSESSMENT OF RISK TO DISTRIBUTION WORKERS

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Ovaj rad predstavlja analizu rizika stradavanja radnika na održavanju postrojenja srednjeg napona distribucijske tvrtke. Proizašao je iz niza istraživanja (povrede na radu, vrijeme na održavanju postrojenja, kvarovi sa zemljom i kvarovi uzemljivača) i predstavlja skup svih prikupljenih relevantnih informacija o ugrozi radnika.

Važnost ovoga rada je što se u osnovi bavi kvarovima, zastojima, prekidima, ali i popravcima (predviđanjem, otkrivanjem i otklanjanjem kvarova), održavanjima, obnavljanjima, unaprjeđenjima i poboljšanjima tehničkih sustava, kao i posljedicama kvarova, kako u tehničkim sustavima, tako i u okolišu tehničkih sustava.

Radnici distribucije električne energije najvećim su dijelom svog radnog vremena na poslovima održavanja elektroenergetskih objekata, tj. električnih mreža i postrojenja srednjeg i niskog napona. Tijekom rada nalaze se u potencijalno opasnoj okolini koja može ugroziti njihovo zdravlje i život. Naravno da moraju biti obučeni za rad na siguran način i koristiti sredstva zaštite na radu, no opasnosti se time ne uklanjaju u potpunosti, nego se tek time smanjuje mogućnost ozljede i njezina veličina. Sve tvrtke, pa i one koje se bave distribucijom električne energije, vode računa o troškovima u kojima veliki dio otpada na troškove ljudskog rada. Trošak je stoga i ozljeda radnika za vrijeme rada, što zbog bolovanja, što zbog mogućih odšteta koje će sve više biti značajan faktor u poslovanju tvrtke. Stoga je potrebno unaprijed sagledati sve potencijalne opasnosti koje mogu ugroziti zdravlje i život radnika za vrijeme rada na održavanju. Upravljanje takvim rizicima postat će sve više zadaća svih tvrtki, ne toliko iz humanih razloga, koliko iz razloga držanja troškova pod kontrolom.

This article presents an analysis of the risk to workers maintaining the medium-voltage facilities of distribution companies, as derived from a series of investigations (injuries at work, time spent on equipment maintenance, ground faults and failures in the grounding system) and represents a group of all the relevant information collected on hazards to workers.

The importance of this study is that it is basically concerned with failures, stoppages and interruptions but also repairs (the forecasting, detecting and eliminating of failures), maintenance, replacement, advancements and improvements in the technical systems, as well as the consequences of failures in technical systems and the surroundings thereof. Electricity distribution workers spend most of their working time on the tasks of maintaining electric power facilities, i.e. electricity networks and medium-voltage and low-voltage electric power facilities. While they are working, they are in a potentially hazardous environment that can endanger their health and lives. Naturally, they must be trained to work in a safe manner and use protective equipment. This does not completely eliminate the hazards but in this way the potential for injury and the severity thereof are reduced. All companies, including those engaged in the distribution of electrical energy, take costs into account, much of which are for human labor. Worker injury during working time is also an expenditure, due to sick leave and potential damages, which will be increasingly significant factors in company operations. Therefore, it is important to review all the potential hazards that can endanger the health and life of a worker during maintenance work. The management of such risks will become a growing task for all companies, less for humane reasons than for keeping costs under control.

Ključne riječi: gradska trafostanica 10(20)/0,4 kV, kvar, mreža i postrojenje srednjeg napona, pokazatelj pouzdanosti, povrede na radu, rizik, sustav uzemljenja, vrijeme održavanja

Key words: failure, grounding system, injury at work, maintenance time, medium-voltage network and facilities, 10(20)/0,4 kV municipal substation, reliability index, risk

1 UVOD

Ljudska priroda potiče na uporabu svega vrjednijeg radi ostvarenja povećanja vrijednosti. Tako su u posljednje vrijeme i tehnički sustavi prijenosa i distribucije električne energije pojačano izlagani riziku kako bi svojim radom donosili povećanje vrijednosti svom vlasniku.

Prodaja električne energije kupcima, u Hrvatskoj, ovisi (još više u neposrednoj budućnosti) i o kvaliteti kao i o količini isporučene električne energije, a to pak ovisi o mjestu, broju i dužini trajanja kvarova opreme. Mjesto i broj kvarova opreme ovise o veličini potrošnje, o stanju opreme kao i o njenom održavanju. O stanju opreme također ovisi i rizik stradavanja radnika koji je održavaju. No, istodobno ti radnici na održavanju svojim radom povećavaju njezinu kvalitetu, što smanjuje broj kvarova i broj mjesta kvara te to traži povećanje njihovog angažmana. Veći radovi na održavanju znače i veći rizik od stradavanja radnika. Stoga se postavljaju pitanja: koliko često moraju ekipe odlaziti u postrojenja zbog održavanja, koji je rizik od nesreća na radu od udara električne energije za radnike distribucije, kako smanjiti te rizike?

2 OSNOVNE POSTAVKE TEORIJE RIZIKA

2.1 Pretpostavke

— postrojenja nemaju stalnu posadu pa su za preventivno, korektivno i kombinirano održavanje potrebne planirane posjete ekipa radnika i njihove radne aktivnosti u potencijalno opasnom okolišu,
— postrojenje bi zbog lošijeg održavanja bilo sklonije kvarovima, nerentabilnije, ali i opasnije za radne ekipe,
— postoji i stanje održavanja kada bi prečesto i preveliko održavanje značilo veliki trošak za rad ekipa, a raspoloživost postrojenja (kvaliteta postrojenja) se ne bi toliko bitno dodatno povećala,
— u postrojenju se može dogoditi potencijalno opasno stanje za radnike na održavanju kada se za vrijeme njihovog boravka (događaj A) dogodi kvar u mreži ili ovom ili susjednom postrojenju 10 kV (događaj B) s velikom strujom kvara kroz uzemljivač. To stanje može biti još opasnije, ako u postrojenju u tim trenucima postoji i makar djelomični kvar uzemljivača (događaj C).

Jedan od prioritetnih rizika je stradavanje radnika u pogonu. Za svaki prioritetni rizik

1 INTRODUCTION

It is in human nature to utilize everything of value in order to create increased value. Thus, in recent times there has been increased risk exposure in technical systems for the transmission and distribution of electricity in order for operations to yield increased value to their owners.

The sale of electricity to customers in Croatia also depends (and will depend even more so in the immediate future) on the quality as well as the quantity of electricity supplied, and thus upon the location, number and duration of equipment failures. The location and number of equipment failures depend upon consumption, the condition of the equipment and its maintenance. The risk of harm to the workers who maintain the equipment also depends upon its condition. However, at the same time these maintenance workers are increasing the quality of the equipment, thereby reducing the number of failures and the number of failure sites, which requires increased engagement on the workers' part. Increased maintenance work also means greater risk of harm to workers. Therefore, the following questions are posed: how often must teams go out to the equipment for maintenance, what are the risks of work-related accidents from electrical shocks to distribution workers and how can these risks be reduced?

2 THE BASIC THESIS OF RISK THEORY

2.1 Assumptions

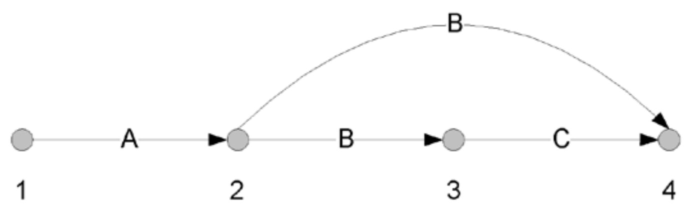
— Facilities do not have permanent crews. Therefore, for preventive, corrective or combined maintenance it is necessary to call in a team of workers and organize their working activities in a potentially hazardous environment.
— Poor maintenance would make facilities would be more susceptible to failures, unprofitable but also hazardous for working teams.
— There is also a state of maintenance when overly frequent and excessive maintenance would signify a significantly large expense for the services of the team, and the availability of the facility (quality of the facility) would not be significantly increased.
— In a facility, a potentially hazardous state for maintenance workers can occur when (Event A) a failure occurs while they are present in the network of either this or a neighboring facility of 10 kV (Event B), with high fault current flowing through the grounding electrode. This state can be even more dangerous if at these moments there is even a partial failure of the grounding system of the facility (Event C).

utvrđuje se njegov rizični lanac i daje pripadni model osnovnog uzroka, neposrednih uzroka, incidenata, akcidenta, neposrednih posljedica i zakašnjelih posljedica:

— osnovni uzrok: pojava napona na uzemljenim metalnim masama (B) ili/i s djelomičnim kvarom uzemljivača (B+C),
— neposredni uzrok: boravak radnika u postrojenju (A),
— incident: potencijalno opasni događaj za radnike u postrojenju, trenutak kvara, B, B+C,
— akcident: događaj strujno-naponskog udara kojem je ili su izloženi radnik/ci za vrijeme izvođenja radova na održavanju elektroenergetskog postrojenja,
— neposredne posljedice: ozljeda, odnosno smrt radnika zbog utjecaja strujno-naponskog udara na tijelo,
— zakašnjele posljedice: ozljeda, smrt, patogene promjene u porodici i društvu, materijalne štete.

One of the priority risks is harm to a worker during operation. For each priority risk, the risk chain is determined and the corresponding model of the basic cause, indirect causes, incidents, accidents, direct consequences and delayed consequences is provided:

— basic cause: voltage occurring on grounded metallic masses (B) and/or partial failure of the grounding system (B+C),
— indirect cause: presence of the worker in the facility (A),
— incident: potentially dangerous event to workers in the facility, moment of failure, B, B+C,
— accident: electrical shock event to which the workers are exposed while performing maintenance work on an electric power facility,
— indirect consequences: the injury or death of a worker due to the effect of an electrical shock event on the body,
— delayed consequences: injury, death, pathogenic changes in the family and society, pecuniary damages.



Slika 6 — Model rizika
Figure 6 — Risk model

Komponenta:

— A — prisutnost radnika u postrojenju (samo u radno vrijeme, tj. od 7 do 15 sati),
— B — kvar u distribucijskoj mreži (10 kV, svi kvarovi sa zemljom),
— C — kvar uzemljivača koji taj rizik čini još opasnijim.

Components:

— A — presence of workers in the facility (only during working hours, i.e. from 7 a.m. to 3 p.m.),
— B — failure in the distribution network (10 kV, all ground faults),
— C — fault in the grounding system, increasing the hazard of this risk.

2.2 Osnovne postavke

— sustav je cjelina koja stvara izlaze Y za dane ulaze X,
— sastoji se od podsustava (oprema, operatori) koji su povezani slijedno (serijski) ili sprežno (paralelno) koji su također sustavi,
— sustav radi pod upravom i nadzorom čovjeka, jednog ili više njih. Nazivamo ih rukovodni posrednici ili agenti,
— svaki agent koristi resurse sustava R (oprema, radnici) u okolišu sustava E, tako da sustav generira izlaz Y u jedinici vremena iz

2.2 Basic assumptions

— The system is a whole entity, which yields output Y for the given input X.
— It consists of subsystems (equipment, operators) connected in a series or in parallel, which are also systems.
— The system operates under the control and supervision of one or more persons. Let us call them managerial intermediaries or agents.
— Every agent uses the resources of the system R (equipment, workers) in the system environment E, so that the system generates output Y in a time

ulaza X. Y je tako propusna moć sustava,

- okoliš sustava E (elektroenergetsko postrojenje) skup je nužnih resursa R koji su neograničeni i daleko od svog punog kapaciteta,
- sustavni resursi R pokretni su iz jednog u drugi okoliš sustava E.
- ako je najveći iznos izlaza Y neki I tada se kaže da je propusna moć sustava. I se mjeri u jedinicama izlaza po jedinici vremena. Katkada sustav ima više izlaza, no uvijek se može navesti koji je to glavni izlaz i ostale smatrati manje važnima, nusproizvodima glavnog izlaza. U većini slučajeva ti odnosi su linearno proporcionalni, pa se govori o glavnom proizvodu sustava, npr. od 2 400 MVA·h na dan, te o nusproizvodu od 8 sati rada operatora u sustavu na dan,
- osnovna jednadžba sustava je:

unit from input X. Y is thus the throughput capacity of the system

- The system environment E (electric power facility) is a group of necessary resources R that are unlimited and operating far below their full capacity.
- System resources R are transportable from one system environment E to another.
- If the highest output value is Y, let I be the system throughput capacity. I is measured in output units per unit of time. Sometimes a system has several outputs but it is always possible to state which is the main output and consider the others to be of less importance, secondary products of the main output. In the majority of cases, these relations are linearly proportional. We speak of the main system product, for example of 2 400 MVA·h per day, and of the byproduct of 8 hours of work by the operator in the system per day.
- The basic equation of the system is as follows:

$$I = k \cdot R \,, \tag{1}$$

gdje je:

I — propusna moć sustava,
R — je resurs sustava,
k — je konstanta proporcionalnosti.

Po izrazu (1) propusna moć raste linearno proporcionalno s resursima. Jedinica kvantizacije je B. Sustav dakle posjeduje $n{\cdot}B$ resursa,

- podjela jednog resursa, npr. u vremenu, moguća je ako se jedan resurs koristi u jednom vremenskom intervalu za jednu, a u drugom za drugu namjenu. Označi li se sa S razina podjele resursa, tada je za m mogućih uporaba resursa $S = m - 1$.
- podjela resursa je moguća i u prostoru i u vremenu, naravno, ukoliko takve akcije imaju negativnu interakciju. Propusna moć i razina podjele resursa odnose se kao:

where:

I — system throughput capacity,
R — system resources,
k — proportionality constant.

According to Expression (1), growth in the throughput capacity is linearly proportional to resources. The unit of quantization is B. Thus, the system possesses $n{\cdot}B$ resources.

- Resource sharing, e.g. in time, is possible if a resource is used in one time interval for one purpose and in another time interval for another purpose. If S indicates the level of resource sharing and m indicates the number of the potential uses of the resource, then $S = m - 1$.
- Resource sharing is also possible in space and in time, naturally if such actions have negative interaction. The relation between throughput capacity and the level of the resource sharing is as follows:

$$I = k \cdot R(1 + S) \,, \tag{2}$$

tj. propusna moć raste linearno proporcionalno razini podjele resursa.
Podjela resursa mora se ograničiti maksimalnom mogućom razinom podjele F,

- osnovna jednadžba rizika dana je izrazom preko očekivane propusne moći I (Bradley, James, 2002, [1]):

i.e. throughput capacity increases with linear proportionality to the level of the resource sharing.
Resource sharing must be limited by the maximum possible level of division F.

- The basic risk equation is expressed by the expected throughput capacity I (Bradley, James, 2002, [1]):

$$I' = R \cdot [k + c \cdot r(E) - r(E)] = R \cdot [k + (c-1) \cdot r(E)] \,, \tag{3}$$

gdje su:

r*(E)* — rizik po jedinici *B* resursa, tj. rizik gubitka propusne moći u ovisnosti u okolišu *E* s obzirom na sustav, a

c — koeficijent učinkovitosti rizika (*c* je konstantan za učinkovit okoliš).

Ulaganja u paralelne resurse, dovode do pretvorbe mogućeg gubitka u izvjesni dobitak.

Osnovno je za svaki rizik odrediti sljedeće parametre:

I — propusna moć,
R — resurs,
k — konstanta propusne moći,
r*(E)* — rizik po jedinici okoliša, tj. mogući gubitak propusne moći u jedinici vremena u sustavu mjeren prema jedinici *B* resursa, a ne prema propusnoj moći sustava. Odatle je r*(E)* srednji očekivani rizik gubitka (*SOG*) jedinice *B* resursa *R*, npr. rizik ozljeđivanja radnika na dan.
S — razina podjele resursa,
c — koeficijent učinkovitosti rizika (*c* ovisi o učinkovitosti okoliša, tako da ukoliko se može dozvoliti povećanje propusne moći, tada se iz tog povećanja može izračunati *c* iz izraza (3)).

Primjenom izraza (2) i (3) dobiva se očekivana propusna moć:

where:

r*(E)* — risk per unit of *B* resource, i.e. the risk of loss in throughput capacity depending on the environment *E* in which the system operates, and

c — risk efficiency coefficient (*c* is constant for the for the efficient environment).

Investment in parallel resources leads to the transformation of potential loss into a certain profit.

For each risk, following basic parameters must be determined:

I — throughput capacity,
R — resource,
k — throughput capacity constant,
r*(E)* — risk per environmental unit, i.e. potential throughput capacity loss in a time unit in the system measured according unit *B* of the resource and not according to the system throughput capacity. Therefore, r*(E)* is the mean expected loss risk (*SOG*) of unit *B* of resource *R*, e.g., the risk of worker injury per day.
S — the level of resource sharing,
c — risk efficiency coefficient (*c* depends on the efficiency of the environment, so that if it is possible to permit increased throughput capacity, from this increased capacity it is possible to calculate *c* from Expression (3)).

Through the application of Expressions (2) and (3), the expected throughput capacity is obtained:

$$I' = R \cdot (1+S) \cdot [k + (c-1) \cdot r(E)] \,. \tag{4}$$

2.3 Kvalitativni model specifičnog rizika - rizik stradavanja radnika na održavanju

Radnici dolaze u elektroenergetsko postrojenje da obave radove prema planu održavanja. Postoji rizik da se za vrijeme njihovog boravka (A) dogodi kvar, (B) u tom ili susjednim postrojenjima i/ili kvar na uzemljivaču (C), što sve rezultira povećanom opasnošću od ozljeđivanja radnika. Sljedeći su kvalitativni parametri rizika:

— propusna moć *I* je broj radnika koji borave na mjestu rada, čovjek po mjestu rada,
— resurs *R* je sposobnost i znanje radnika,

2.3 Qualitative model of a specific risk – the risk of harm to a maintenance worker

Workers enter an electric power facility to perform work according to the maintenance plan. There is the risk that while they are there (A) a failure will occur,(B) in this or neighboring facilities and/or a fault in the grounding system (C), all of which increases the hazard of worker injury. The following are the qualitative risk parameters:

— throughput capacity *I* is the number of workers who are present at the place of work, person per workplace,
— resource *R* is the ability and knowledge of the workers, their training for work, the total amount

njihova uvježbanost za rad, ukupan iznos svih mogućih, čovjek·sati rada na pojedinom poslu održavanja,

— propusna konstanta k je omjer broja ljudi i njihovih znanja na poslovima održavanja, (čovjek/mjesto rada)/čovjek·sati rada na određenom poslu) = 1/(mjesto rada·sati rada na pojedinom poslu),
— rizik $r(E)$ je rizik gubitka radnika zbog npr. ozljeđivanja u procesu izvođenja radova na održavanju,
— jedinično smanjenje rizika c je povećanje propusne moći (broja radnika) zbog brižljivo izvedenih radova na održavanju, kvaliteta i brzina izvođenja radova, i
— S je mogućnost uporabe pojedinog radnika za vrijeme radnog vremena i u drugim elektroenergetskim postrojenjima, ako posao završe kraće nego što je planirano.

Elektroenergetska se postrojenja mogu s naslova njihova stanja opisati jednim atributom ocjene stanje opreme S_o. Za takav se sustav može izgraditi odgovarajuća shema stanja koja polazi od dekompozicije sustava po principu odozgora-nadolje. Atribut ocjene stanja opreme je trenutačna veličina koja obuhvaća sve komponente sustava i opisuje se jednim brojem između 0 i 1. Stanje $S_o = 0$ odgovaralo bi totalnom nefunkcioniranju sustava (sve neispravno), a stanje $S_o = 1$ savršeno funkcioniranje sustava (sve komponente ispravne). Obično je stanje negdje oko $S_o = 0{,}6$, a kada padne ispod $S_o = 0{,}4$ tada su potrebne znatnije intervencije u njenom održavanju. Ocjena stanja uključuje i neodređenost tako da je njen stvarni opis dan intervalom npr. $S_o = [0{,}55,\ 0{,}59]$.

Zbog jednostavnosti analitičkog pristupa pretpostavit će se stacionarno stanje atributa ocjene stanja opreme te dane granice neodređenosti poznavanja tog stanja.

Isto tako će se pretpostaviti postojanje atributa ocjene stanja vještina radnika na održavanju s pripadnom intervalnom procjenom njenog nepoznavanja $S_{ij} = [0{,}7,\ 0{,}85]$ Neka je i ta procjena i njezina neodređenost stacionarna veličina.

2.4 Učinkovitost okoliša i rizik

Razmatraju se dva okoliša promatranog sustava: E_1 i E_2. Pretpostavlja se da je okoliš E_1 bez rizika pri čemu sustav s resursima R ima stabilni kapacitet $I=k \cdot R$ u jedinici vremena. Okoliš E_2 je isti kao E_1 samo s rizikom. Pretpostavlja se da je propusna moć sustava u E_2 jednaka $k \cdot R + D$ u jedinici vremena uz uvjet da se srećom nije dogodio hazard kojeg se riskiralo (D su rizični dobici). No, kako se u rizičnom okolišu mogu

of all possibilities, man·hours of work on an individual maintenance job,

— throughput constant k is the ratio of the number of people and their knowledge regarding maintenance jobs, (person/workplace)/man·hours of work on a specific job) = 1/(workplace ·hours of work on an individual job),
— risk $r(E)$ is the risk of the loss of a worker due to, for example, injury during the process of performing maintenance work,
— the risk reduction unit c is increased throughput capacity (number of workers) due to carefully performed maintenance work, quality and speed of the performance of the work, and
— S is the possibility of also using an individual worker at other electric power facilities during working hours if a job is completed earlier than planned.

Electric power facilities can be described by an attribute of the assessed state of the equipment S_o. For such a system, it is possible to construct a corresponding diagram that starts from the decomposition of the system according to the top-down principle. The attribute of the assessment of the state of the equipment is the instantaneous value that covers all the system components and is described by a number between 0 and 1. The state $S_o = 0$ would correspond to a totally nonfunctioning system (everything out of order) and the state $S_o = 1$ would correspond to a perfectly functioning system (all the components in good working order). Usually, the state is somewhere around $S_o = 0{,}6$, and when it drops below $S_o = 0{,}4$ significant interventions are necessary regarding its maintenance. Evaluation of the state also includes indeterminacy, so that its actual description is given by an interval, for example $S_o = [0{,}55,\ 0{,}59]$.

Due to the simplicity of the analytical approach, a stationary state of the attributes of the assessment of the state of the equipment and the given limits of indeterminacy regarding knowledge of that state will be assumed.

Similarly, the existence of the attributes of the assessment of the state of the skill of the maintenance workers will be assumed with the corresponding interval of the assessment of the lack of knowledge thereof, $S_{ij} = [0{,}7,\ 0{,}85]$ Let this assessment and its indeterminacy be a stationary value.

2.4 Environmental efficiency and risk

Two environments of the studied system are considered: E_1 and E_2. It is assumed that environment E_1 is without risk, whereby the system with resources R has a stable capacity $I=k \cdot R$ in a time unit. Environment E_2 is the same as E_1 except with risk. It is assumed that the throughput capacity of system E_2 is equal to $k \cdot R + D$ in a unit of time under the condition that with luck the hazard risked has not occurred (D

očekivati i neki gubici G u jedinici vremena u prosjeku, tada je propusna moć sustava jednaka:

are risk gains). However, since in a risk environment some losses G may be expected in a unit of time on average, the throughput capacity of the system is as follows:

$$I = k \cdot R + D - G \ . \qquad (4a)$$

Tada su G srednji očekivani gubici (SOG) s obzirom na bez rizični rad s propusnom moći $I = k \cdot R + D$.

Situaciju sa $D > G$ može se smatrati dugoročno ispravnim, a $D < G$ dugoročno neispravnim režimom korištenja okoliša sustava.

Odatle se može zaključiti da su rizik i propusna moć sustava linearno proporcionalne veličine.

Najveći omjer D/G koji se može postići u nekom okolišu naziva se koeficijent učinkovitosti c. Uvede li se zamjena $c - 1$ $(c - 1 = b)$ u izraz (4) dobiva se često korišteni oblik jednadžbe propusne moći sustava:

Then G stands for the mean expected losses (SOG) regarding no-risk operation with a throughput capacity of $I = k \cdot R + D$.

The situation with $D > G$ can be considered as justified over the long term, and $D < G$ can be considered as an unjustified regime over the long term use of the environment system

Therefore, it may be concluded that the risk and throughput capacity of the system are linearly proportional values.

The highest ratio of D / G that can be achieved in an environment is called the efficiency coefficient c. If b is substituted for $c - 1$ $(c - 1 = b)$ in Expression (4), a frequently used form of the equation is obtained for the throughput capacity of a system:

$$I' = R \cdot [k + b \cdot r(E)] \ , \qquad (5)$$

koji se rabi u financijama i gdje je:

- R — ukupno uložena suma,
- k — garantirana kamata,
- $b \cdot r(E)$ — jedinična ekstra dobit za rizično ulaganje.

Primjer

Za tehnički sustav koji se promatra, a koji je dio DP Elektroslavonija Osijek za grad Osijek, organizacijska jedinica Pogon Osijek sa jedinom zadaćom održavanja elektroenergetskog postrojenja vrijedi:

300 trafostanica 35/10 kV (10 kom) i 10/0,4 kV (290 kom), sa 140 radnika na održavanju i s prosječno 12 sati rada po svakoj trafostanici godišnje (iz istraživanja vremena održavanja).

Iz toga slijedi:

$R = 300 \cdot 12 = 3600$ čovjek·sati i
$I = 140$ radnika, pa je
$k = 0{,}038\ 888$ jedinica resursa R po godini u nerizičnoj situaciji.

which is used in finances and where:

- R — the total sum invested,
- k — guaranteed interest,
- $b \cdot r(E)$ — unit of extra profit for risk investment.

Example

For the technical system considered, the following apply for the organizational unit Pogon Osijek, which is a part of the distribution territory DP Elektroslavonija Osijek for the city of Osijek and has the sole task of maintaining the electrical power facilities:

300 substations, of which 10 are 35/10 kV and 290 are 10/0,4 kV, with
140 maintenance workers and an average of
12 man-hours of maintenance work per substation annually (from a study of maintenance time).

Therefore:

$R = 300 \cdot 12 = 3600$man·hours and
$I = 140$ workers, and thus
$k = 0{,}038\ 888$resource unit R per year in a non-risk situation

Iz istraživanja povreda na radu proizlazi 36 povreda od električne energije u 30 godina, što iznosi 1,166 66 povreda godišnje, ili u relativnom iznosu oko 0,002.

Ako se ustanovi učinkoviti okoliš E s takvim, upravo navedenim srednjim očekivanim gubitkom (rizikom gubitka radnika) $SOG = 0{,}002$ jedinice po godini, onda povećanje propusne moći na 150 jedinica traži:
$I' = 3\,600(0{,}038\,888 + x) = 150,$
Odatle:
$x = b \cdot r(E) = 0{,}002\ SOG\ b = 0{,}002\,778\,6,$
pa je:
$b = 1{,}389\,3$ ili $c = 2{,}389\,3.$

Najveća propusna moć bit će $3600 \cdot (0{,}038\,888 + 2{,}389\,3 \cdot 0{,}002) = 157{,}2$ čovjek·sati. Pitanje je kako će se pokazati najmanja propusna moć.

2.5 Numerički pokus određivanja jednostavnog rizika

Niz podataka za sustav S dan je kao slučajna veličina s podacima obrađivanog sustava.
Za izračun jednostavnog rizika kod procesa održavanja potrebno je poznavati sljedeće podatke:

resurs R — ukupan broj raspoloživih čovjek·sati svih ekipa za održavanje,
propusna moć I — potreban broj ekipnog rada na održavanju sustava izražen kao potrebni čovjek·sati.

Neka se zamisli stanje Pogona Osijek kod održavanja distribucijskog sustava grada Osijeka koje se može realizirati u periodu od 10 godina, a želi se povećanje resursa za 50 jedinica godišnje. Pri tome se pretpostavlja povećanje broja radnika u svakoj godini.

From a study of worker injuries, it was shown that there were 36 injuries from electricity in *30* years, which amounts to 1,166 66 injuries, or a relative figure of approximately 0,002.

If the efficient environment E is established with the aforementioned mean expected loss (the risk of worker loss) $SOG = 0{,}002$ units per year, then the increased throughput capacity to 150 units requires the following:
$I' = 3\,600(0{,}038\,888 + x) = 150,$
from which:
$x = b \cdot r(E) = 0{,}002 \cdot b = 0{,}002\,778\,6,$
and thus:
$b = 1{,}389\,3$ ili $c = 2{,}389\,3.$

The greatest throughput capacity will be $3600 \cdot (0{,}038\,888 + 2{,}389\,3 \cdot 0{,}002) = 157{,}2$. The question is how the minimum throughput capacity will be represented.

2.5 Numerical test to determine simple risk

A series of data for system S is given as a random value with data from the system considered.
For the calculation of the simple risk in the process of maintenance, it is necessary to know the following information:

resource R — the total number of available man hours. of all the maintenance teams,
throughput capacity I — the man·hours of system maintenance teams required.

Let us imagine the state of the Osijek plant regarding the maintenance of the distribution system of the city of Osijek which can be achieved within a period of 10 years, and it is desired to increase resources by 50 units annually. An increased number of workers is assumed for each year.

Tablica 1 — Numerički primjer
Table 1 — Numerical example

Redni broj / Ordinal No.	Ukupan broj raspoloživih ekipa (čovjek·sati/god) / Total number of available teams (man-hours/year) R resurs / resource	Potreban broj radnika (čovjek·sati) / Required number of workers (man-hours) I propusna moć / throughput capacity
1	3 450	140 diff =–10
2	3 500	142 diff = –8
3	3 550	145 diff = –5
4	3 600	148 diff = –2
5	3 650	149 diff = –1
6	3 700	151 diff = 1
7	3 750	152 diff = 2
8	3 800	155 diff = 5
9	3 850	158 diff = 8
10	3 900	160 diff = 10
	Ukupno / Total 36 750	Ukupno / Total 1 500 diff abs. = 52

diff – razlika / difference
abs – apsolutna (vrijednost) / absolute (value)
int – cijeli broj / integer

Ako se pretpostavi planirani resursni kapacitet 3800 čovjek·sati, i planiranu propusnu moć za 10 godina na 150 čovjek·sati, planirani je koeficijent resursa je 150/3 800 = 0,039 473 6.

Izračun srednjeg očekivanog gubitka *SOG* za proces na tablici je prema izrazu:

$$SOG = \sum_{n} diff(\text{int})_{\text{abs}} \, , \qquad (6)$$

gdje je razlika interventnih radova računata prema srednjem broju intervencija, a n je broj perioda računanja, godina.

Iz gornjih podataka izlazi da je SOG = 5,2. Izračun $r(E)$ zasnovan je na omjeru SOG i resursnog kapaciteta i iznosi $r(E)$ = 5,2/3 800 = 0,001 368 4.

Primjena jednadžbe rizika, izraz (3), daje uz pretpostavljeni c = 1,25, I' = 3 675 · (0,039 473 6 + 0,25 · 0,001 368 4)=144,17 propusnu moć čovjek·sati/god. što je manje od planiranih 150 čovjek·sati/god.

Sa:
c = 1,5 I' = 147,58 čovjek·sati/god.,
c = 1,75 I' = 148,84 čovjek·sati/god.,
c = 2 I' = 150,09 čovjek·sati/god., te
c = 2,25 I' = 151,35 čovjek·sati/god., što bi bila maksimalna vrijednost propusne moći.

Srednja razlika je 151,35 – 147,58 = 3,77 čovjek·sati/god.
Najveća dozvoljena srednja razlika bi bila dvostruka vrijednost, tj. 7,54 čovjek·sati/god.
Vjerojatni minimum protočne moći, tj. radnika bi tako bio 151,35 – 7,54 = 143,81, tj. 143 čovjek·sati/god.

Slike 2 do 4 pokazuju međusobne odnose rizika, resursa te propusne moći.

If a planned resource capacity of 3800 man·hours and a throughput capacity for 10 years of 150 man·hours are assumed, the planned resource coefficient is 150/3 800 = 0,039 473 6.

The calculation of the mean expected loss *SOG* for the process on the table is according to the expression:

where the difference in the intervention work is calculated according to the mean number of interventions and n is the number of the calculation periods, years.

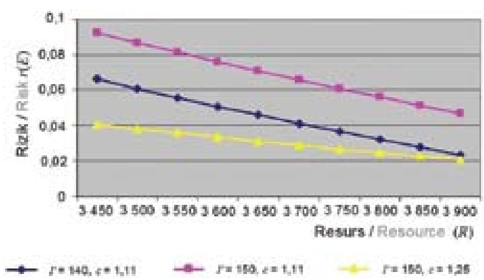
From the above data, it follows that SOG = 5,2. The calculation of $r(E)$ is based upon the ratio of the SOG and the resource capacity, amounting to $r(E)$ = 5,2/3 800 = 0,001 368 4.

Application of the risk equation, Expression (3), under the assumption c = 1,25, I' = 3 675 · (0,039 473 6 + 0,25 · 0,001 368 4)=144,17 yields throughput capacity man·hours/year, which are fewer than the planned 150 man·hours/year

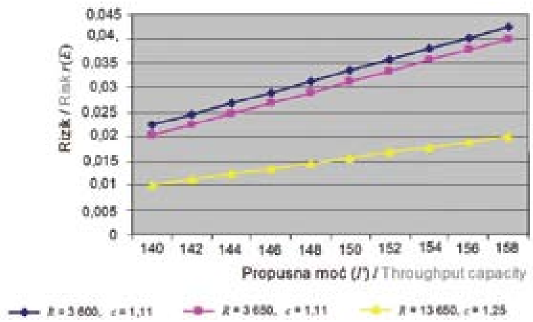
with:
c = 1,5 I' = 147,58 man·hours/year,
c = 1,75 I' = 148,84 man·hours/year,
c = 2 I' = 150,09 man·hours/year, and
c = 2,25 I' = 151,35 man·hours/year, which would be the maximum throughput capacity value.

The mean difference is 151,35 – 147,58 = 3,77 man·hours/year
The maximum permitted difference would be twice this value, i.e. 7,54 man·hours/year
The probable minimum throughput capacity, i.e. workers, would then be 151,35 – 7,54 = 143,81, i.e. 143 man·hours/year

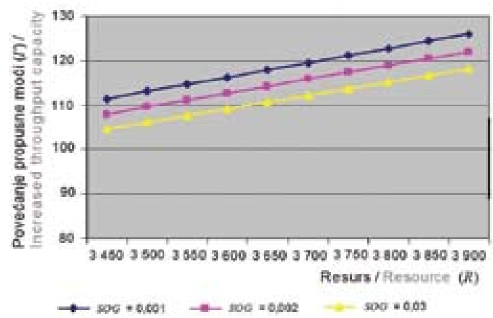
Figures 2 to 4 present the relations among risks, resources and throughput capacity.



Slika 2 — Odnos rizika i resursa
Figure 2 — Risk/Resource Ratio



Slika 3 — Odnos rizika i propusne moći
Figure 3 — Risk/Throughput capacity ratio



Slika 4 — Odnos povećanja propusne moći i resursa
Figure 4 — Increased throughput capacity/resource capacity

3 VJEROJATNOSTNA METODA ODREĐIVANJA RIZIKA

Vjerojatnost da se radnik nalazi na poslovima održavanja (komponenta A – prema istraživanju vremena potrebnog za održavanje) u trafostanici 35/10 kV je:

$P_{35/10}$(A)= 66,08/8 760 = 0,007 54 po trafostanici i godini, a kako ih je 10 to je vjerojatnost boravka u bilo kojoj 0,075 4,

dok je u TS 10/0,4 kV:

$P_{10/0,4}$(A)= 10,41/8 7600 = 0,001 19 po godini i jednoj TS, a kako ih je 290 to je vjerojatnost boravka u bilo kojoj 0,345 1.

Vjerojatnost da je kvar u postrojenju za vrijeme radnog vremena od 7:00 do 15:00 sati (komponenta B prema istraživanju kvarova sa zemljom u postrojenju) je:

P(B)=48 %.

Vjerojatnost da je pri tom djelomični kvar uzemljivača (komponenta C prema istraživanju pouzdanosti uzemljivača) je od P(C)=0,1 % (osnovni uzemljivač), preko 1,85 % (uzemljivač mreže niskog napona) do 2,4 % (uzemljivač susjednih TS preko VN kabela).

Stoga nastupaju rizične situacije za stradavanje radnika:

a) Radnik se nalazi u postrojenju na poslovima održavanja, vjerojatnost situacije 0,075 4 za TS 35/10 kV, a 0,345 1 za TS 10/0,4 kV.

3 THE PROBABILITY METHOD OF RISK ASSESSMENT

The probability that a worker will find himself on a maintenance assignment (component A – according to a study on the time required for maintenance) in a 35/10 kV substation is:

$P_{35/10}$(A)= 66,08/8 760 = 0,007 54 per substation per year, and since there are 10 of them the probability of being in any of them is 0,075 4,

while in a 10/0,4 kV substation it is

$P_{10/0,4}$(A)= 10,41/8 7600 = 0,001 19 per year per substation. Since there are 290 of them, the probability of being in any one of them is 0,345 1.

The probability of a failure in a facility during working hours from 7 a.m. to 3 p.m. (component B – according to a study of ground faults in the facilities) is as follows:

P(B)=48 %.

The probability that a partial failure of a grounding system would occur then (component C – according to a study on the reliability of grounding electrodes) is P(C)=0,1 % (main grounding electrode), 1,85 % (grounding electrode of a low voltage network) up to 2,4 % (grounding electrode of neighboring substations via a high voltage cable).

Therefore, risk situations for injury to workers are as follows:

a) A worker finds himself at a facility on a maintenance job, the probability of the situation is 0,075 4 for a 35/10 kV substation and 0,345 1 for a 10/0,4 kV substation.

b) Vjerojatnost situacije da se upravo u tom trenutku dogodi kvar je $0,48 \cdot 0,075\,4 = 0,036\,2$ za TS 35/10 kV, a $0,48 \cdot 0,345\,1 = 0,166$ za TS 10/0,4 kV,
c) Vjerojatnost situacije da se u tom intervalu vremena imamo i djelomični kvar na uzemljivaču $0,036\,2 \cdot 0,001 = 0,000\,036\,2$ za TS 35/10 kV, a $0,166 \cdot 0,001 = 0,000\,166$ za TS 10/0,4 kV.

Slijedi tablica matematičkih vjerojatnosti svih mogućih opasnih stanja u kojem se mogu naći radnici distribucije za vrijeme normalnog svakidašnjeg rada.

b) The probability of a situation that a fault occurs precisely at that instant is $0,48 \cdot 0,075\,4 = 0,036\,2$ for a 35/10 kV substation and $0,48 \cdot 0,345\,1 = 0,166$ for a 10/0,4 kV substation.
c) The probability of a situation that in that time interval we also have a partial failure of the grounding system is $0,036\,2 \cdot 0,001 = 0,000\,036\,2$ for a 35/10 kV substation and $0,166 \cdot 0,001 = 0,000\,166$ for a 10/0,4 kV substation.

The table presents the mathematical probabilities for all the possible hazardous states in which distribution workers can find themselves during normal daily working hours.

Tablica 2 — Matematičke vjerojatnosti rizika
Tablica 2 — Mathematical risk probability

Redni broj / Ordinal no.	Vjerojatnosti / Probabilities				
	Prisutnost radnika (A) / Worker presence (A)			Istodobna pojava kvara (A+B) / Simultaneous occurrence of fault (A+B) (2·0,48)	Istodobna pojava i djelomičnog kvara na uzemljivaču postrojenja slučaj (A+B+C) / Simultaneous occurrence of a partial failure of the grounding system of the facility in the event of (A+B+C) a – osnovni uzemljivač 0,001 / a – main grounding electrode 0,001 b – uzemljenje preko kabela visokog napona 0,024 / b – grounding via a high voltage cable 0,024 c – uzemljenje preko mreže niskog napona, 0,0185 / grounding via a low voltage network 0,0185 ab – 9,78E · 06 ac – 1,07E · 05 bc – 3,25E · 04 (2·3·(a ili / or b ili / or c ili / or ab ili / or ac ili / or bc))
	TS 35/10 kV · za / for 10 TS	TS 10/0,4 kV · za / for 290 TS	Prosječno obje TS/2 / Mean for both substations/2		
1	2			3	4
1a	0,075 4			3,62E · 02	3,62E · 05
1b	0,075 4			3,62E · 02	8,69E · 04
1c	0,075 4			3,62E · 02	6,70E · 04
1ab	0,075 4			7,37E · 07	7,21E · 12
1ac	0,075 4			3,62E · 02	3,87E · 07
1bc	0,075 4			3,62E · 02	1,18E · 05
2a		0,345 1		1,66E · 01	1,66E · 04
2b		0,345 1		1,66E · 01	3,98E · 03
2c		0,345 1		1,66E · 01	3,06E · 03
2ab		0,345 1		1,66E · 01	1,62E · 06
2ac		0,345 1		1,66E · 01	1,77E · 06
2bc		0,345 1		1,66E · 01	5,38E · 05
3a			0,210 25	1,01E · 01	1,01E · 04
3b			0,210 25	1,01E · 01	2,42E · 03
3c			0,210 25	1,01E · 01	1,87E · 03
4ab			0,210 25	1,01E · 01	9,87E · 07
4ac			0,210 25	1,01E · 01	1,08E · 06
4bc			0,210 25	1,01E · 01	3,28E · 05
5					

Usporedba izračuna rizika stradavanja radnika distribucije na poslovima održavanja:
— iskustveni podatak iz prakse: 0,002,
— rezultat Bradley metode: 0,001 368 4,
— rezultati vjerojatnostne metode: 0,001 87; 0,002 4; 0,003 06; 0,003 98.

Comparison of the risk calculations of injury to a distribution worker engaged in maintenance work:
— data from practical experience: 0,002,
— result of the Bradley method: 0,001 368 4,
— results of the probability method: 0,001 87; 0,002 4; 0,003 06; 0,003 98..

4 FINANCIJSKE VELIČINE

Rizik gubitka radnika ozljeđivanjem ili smrću stalno je prisutan još od trenutka, po pozitivnim propisima, kada krene na posao. Stoga je i novčana naknada za izgubljeno zdravlje ili život prisutna i dosta realna. Poslovodstvo tvrtke može bitno utjecati na opasnosti za zdravlje i život unutar radnog procesa. U ovom radu se posebno razmatra rizik od ozljeda na radu tijekom planiranog rada na održavanju distribucijskog elektroenergetskog sustava, i to posebno promatrajući rizike gubitka radnika od udara električne energije.

Stoga se krenulo s istraživanjem ozljeda na radu te je napravljena baza podataka svih ozljeda na radu u DP Elektroslavonija Osijek iz koje je posebno izdvojena Tablica podataka s nezgodama na radu na području grada Osijeka. Tu su izdvojene sve povrede koje uključuju djelovanje električne energije na tijelo radnika, sa svim relevantnim podacima gdje, kada i kako su se dogodile. Iz te tablice slijedi da su rizici gubitka radnika samo od takvih potencijalno opasnih događaja oko 0,2 %.

Sljedeće istraživanje je provedeno stvarajući bazu podataka svih kvarova koji su se dogodili na području grada Osijeka na postrojenjima srednjeg napona tijekom kojih je u pogonskim dnevnicima dispečera ostala zabilješka o isključenju radi djelovanja zaštite ili zemljospojne, ili od jednopolnog ili višepolnog kvara sa zemljom. Tu su se evidentirali svi relevantni podaci o tom događaju uključujući i vrijeme događanja. Analiza pokazuje da se 48 % svih takvih kvarova događa baš u djelatno radno vrijeme, tj. od 7:00 do 15:00 sati. To sigurno djeluje na rizike gubitka radnika povećavajući ga, a zbog mogućeg kontakta s električnom energijom u trenutku kvara.

O vremenu, koje radnici provode na poslovima održavanja u postrojenjima distribucije, a prema važećem Pravilniku o održavanju elektrodistribucijskih objekata i postrojenja, napravljeno je posebno istraživanje. Ono pokazuje da se vremenski najviše radnici zadržavaju u TS 35/10 kV (66 sati po radniku i trafostanici godišnje) i u TS 10/0,4 kV (10,42 sata po radniku i trafostanici godišnje). Uvažavajući broj trafostanica jasno je da potencijalno opasni događaji s velikom strujom kroz uzemljivač bitno povećavaju rizike.

Financijske veličine troškova uzrokovanih povredama na radu, pogotovo vezanih na kontakt s električnom energijom, bilo je vrlo teško skupiti i analizirati, jer se u tvrtki do sada nisu sustavno vodile takve evidencije. To pokazuje kako se

4 FINANCIAL VALUES

The risk of the loss of a worker due to injury or death is constantly present from the moment, according to positive regulations, when the worker goes to work. Therefore, financial compensation for the loss of health or life is present and a realistic consideration. Company management can significantly affect the hazards to health and life within the working process. In this article, risk to a worker during planned maintenance work on an electric power system is specifically discussed, especially regarding the risks of worker loss due to electrical shock.

Therefore, this study began with an investigation of injuries at work. A database was prepared of all the work-related injuries at DP Elektroslavonija Osijek, from which the table data were taken on accidents at work in the area of the city of Osijek. All the injuries were entered that included the effect of electricity on the body of a worker, with all the relevant data, when and how they happened. From this table, it follows that the risk of worker loss solely due to such potentially hazardous events is approximately 0,2 %.

The study was conducted by creating a database of all the failures that occurred in the territory of the city of Osijek at medium voltage facilities during which there were notes in the dispatchers' log books on switching off due to protection tripping or ground faults, or from single-phase or multi-phase ground faults. All the relevant data are entered here on these events, including the times of the events. Analysis shows that 48 % of all such failures occur precisely during working hours, i.e. from 7 a.m. to 3 p.m. This certainly has an effect on the risk of worker loss, increasing it, and due to potential contact with electricity at the moment of the failure.

Regarding the time that the workers spend on maintenance tasks at the distribution facilities and according to the current Regulations on the Maintenance of Electrical Distribution Facilities and Plants, a separate investigation was conducted. It demonstrated that workers spend the most time at 35/10 kV substations (66 hours per worker and substation annually) and at 10/0,4 kV substations (10,42 hours per worker and substation annually). Taking the number of substations into account, it is clear that potentially dangerous events with high fault current flowing through the grounding electrode significantly increase risks.

The financial costs incurred due to injury at work, especially in connection with contact with electricity, were very difficult to collect and analyze because until now such evidence had not been recorded systematically in the company. This shows that until now this company has not paid much attention to instruments for the reduction of such types of financial expendiova kompanija, do sada, nije previše bavila instrumentima za smanjivanje takvih vrsta financijskih troškova. Neki odgovorni ljudi tvrtke osjećaju postupno povećanje te vrste troškova te uviđaju da će ubrzo morati sustavno i daleko češće i kvalitetnije pratiti i procjenjivati takve novčane odljeve radi boljeg poslovanja tvrtke.

U slučajevima povreda na radu radnika distributivne tvrtke, ali i za radnike drugih tvrtki i ostale prolaznike u blizini elektroenergetskih distribucijskih postrojenja, tvrtka je vezana objektivnom odgovornošću zbog dvije činjenice:

— kao imatelj opasne tvari i
— jer se bavi opasnom djelatnošću.

Tu odgovornost isključuje samo:

— viša sila,
— djelovanje treće osobe i
— gruba nepažnja oštećenoga.

Naravno da je potrebno dokazati takvo isključenje što se u sudskoj praksi pokazalo gotovo nemoguće.

U nastavku je dana tablica svih podataka koji su mogli biti prikupljeni, prezentirani i analizirani.

tures. Some responsible people in the company feel that there has been a gradual increase in these types of expenditures and are of the opinion that it will soon be necessary to monitor and assess such monetary outflows systematically and far more often in order to improve company performance.

In cases of worker injuries at distribution companies, but also for workers of other companies and passersby in the vicinity of an electrical distribution facility, a company is objectively liable due to two facts:

— it is the owner of hazardous materials and
— it is engaged in a hazardous activity.

Such liability excludes only the following:

— force majeure,
— the activities of a third person and
— gross negligence of the injured party.

Naturally, it is necessary to prove such exclusions, which in court practice has been shown to be practically impossible.

The table below presents all the data that could be collected, presented and analyzed.

Tablica 3 – Financijske veličine
Table 3 – Financial values

	Uzrok bolovanja / Reason for sick leave	Godina / Year				
		2002.	2003.	2004.	2005.	2006.
Isplaćeno / Amount paid [HRK]	Bolest / Illness	807 949,55	935 791,82	975 232,90		
	Povreda na radu / Injury at work	257 647,42	195 946,20	161 895,44	215 751,84	162 915,56
	Porodiljni / Parental leave	115 370,38	0,00	0,00		
	Njega / Care	48 120,20	43 808,95	38 275,25		
Dani bolovanja / Days of sick leave	Bolest / Illness	4 481	4 406	4 214		
	Povreda na radu / Injury at work	1 177	778	584	572	416
	Porodiljni / Parental leave	879	748	1 008		
	Njega / Care	342	313	339		
Broj slučajeva / Number of cases	Bolest / Illness	421	430	412		
	Povreda na radu / Injury at work	25	45	26	29	21
	Porodiljni / Parental leave	6	9	2		
	Njega / Care	73	54	50		

Na financijske troškove tvrtke nastale zbog povreda na radu, s posebnim naglaskom na povrede s uključenim djelovanjem električne energije, utječu:

— bolovanja,
— troškovi izvođača radova drugih tvrtki na održavanju zbog izostanka radnika,
— naknade imovinske i neimovinske štete,
— troškovi liječenja,

The following influence the financial expenditures of the company that occur due to injury at work, with particular emphasis on injuries that include the effect of electricity.

— sick leave,
— labor costs for maintenance workers from other companies due to worker absence,
— compensation for pecuniary and non-pecuniary damages,

- troškovi zbog kaznene prijave inspektora zaštite na radu,
- troškovi zbog nezgode na radu preko osiguravatelja,
- i drugi direktni i indirektni troškovi, kao npr. troškovi doživotne rente,
- u slučaju smrtne posljedice pojavljuju se troškovi naknade imovinske i
- neimovinske štete koja, po trenutačnoj sudskoj praksi, iznosi do 250 000,00 HRK po članu obitelji oštećenoga.

5 ZAKLJUČAK

Promatrajući samo financijske elemente troškova povreda na radu u Elektroslavoniji Osijek, mogu se formirati sljedeći zaključci:

Kao maksimalna veličina pojavljuje se trošak bolovanja od 10 306,00 HRK po radniku godišnje što pomnoženo s prosječno 30 radnika na bolovanju godišnje iznosi 309 180,000 HRK.

Procjena troškova zbog izostanka radnika s posla pokazuje da je izgubljeno prosječno 705 radnih dana koje bi (ako se na tim poslovima unajme radnici druge tvrtke) trebalo platiti dodatnih gotovo 300 000,00 HRK godišnje.

Treba računati da će troškovi na ime doživotne rente i troškova liječenja, koji su sada oko 150 000,00 HRK godišnje, rasti na veće vrijednosti.

Ako je procjena da se svakih 5 godina dogodi povreda sa smrtnom posljedicom, tada za prosječno 3 člana obitelji na ime naknada imovinske i neimovinske štete treba isplatiti oko 150 000,00 HRK godišnje.

Ukupno svi ti troškovi se mogu procijeniti na 1 000 000,00 HRK po godini što je 33 000,00 HRK po radniku godišnje. Ako se tu posebno izdvoje ozljede na radu nastale kao posljedica djelovanja električne energije i pretpostavi samo dvije takve ozljede godišnje, tada se može reći da bi u tom slučaju ukupni troškovi bili do 200 000,00 HRK po radniku godišnje, s tendencijom strmog uzlaznog rasta.

Većina ovih troškova rast će i unatoč poduzetim mjerama za smanjenje troškova ozljeđivanja radnika, no ako se troškove rizika ugroze radnika na održavanju ne stavi pod kontrolu, za očekivati je eksplozivan rast, jer postrojenja nisu održavana dugo vremena i ulaganja u njih nisu bila dostatna.

- costs of medical treatment,
- costs due to penalties imposed by the work safety inspector,
- costs due to accidents at work via an insurer, and
- other direct and indirect costs, such as costs for life-long financial support.
- in the event of fatal consequences, there are costs for compensation for pecuniary and non-pecuniary damages which, according to current court practice, can be up to 250 000,00 HRK per family member of the deceased.

5 CONCLUSION

Considering only the financial costs of work-related injuries at Elektroslavonija Osijek, it is possible to draw the following conclusions:

The greatest expenditure is the cost of sick leave, 10 306,00 HRK per worker annually, which when multiplied by an average of 30 workers on sick leave annually amounts to 309 180,000 HRK.

Assessment of the costs due to worker absence from work shows that an average of 705 working days are lost for which, if workers from other companies are engaged to do these jobs, it is necessary to pay nearly an additional 300 000,00 HRK annually.

It is necessary to take into account that costs for life-long support and medical treatment, which are currently approximately 150 000,00 HRK annually, will rise.

If it is estimated that every 5 years there will be an injury with fatal consequences, then for an average 3-member family it will be necessary to pay approximately 150 000,00 HRK annually for pecuniary and non-pecuniary damages.

All the expenditures together can be estimated at 1 000 000,00 HRK per year, which is 33 000,00 HRK per worker annually. If work injuries are singled out that occurred as a consequence of the effect of electricity and only two such injuries annually are assumed, then in such a case the total costs would be up to 200 000,00 HRK per worker per year, with a tendency toward sharp increase.

Despite the measures undertaken for reducing the costs of worker injuries, the majority of the costs will rise. However, if the costs of the risks to maintenance workers is not subject to control, explosive growth can be expected because the facilities have not been serviced for a long time and investments in them have not been sufficient.

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