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DETERMINATION OF OPTIMAL WORKING PARAMETARS OF GAS PIPELINE SYSTEM BY RISK ANALYSIS APPLICATION

ODREĐIVANJE OPTIMALNIH PARAMETARA RADA GASOVODNOG SISTEMA PRIMENOM ANALIZE RIZIKA

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Abstract: *The aim of this paper is to present the use of Risk Analysis in gas pipeline system for improving its working performance. During gas functioning of pipeline system in certain situation it is coming to gas consumption increasing by each consumer, that has direct influence on other consumers. Consumption determination as a variable in classical method application, which calculates the pressure drop in discrete manner for defining gas consumption change by individual consumers or consumer centers is very complex problem. Because of that, it is very difficult to obtain picture of gas pipeline system behavior. Applying of Risk Analysis, the solution of problem is simple and of better quality and as simulation method is very useful in accident situation. Gas consumption change is defined by function with adequate change range. Risk simulation is done by using methods of Monte Carlo or Latin Hypercube with a high number of iteration gas pipeline system behavior, which is equivalent to thousand and thousand combinations used in classical method. As a result of Risk Analysis, graph of probability distribution is obtained, which is useful to decision maker for gas consumption managening and control.*

In this paper are shown main characteristics of risk quantification. Also, it is presented risk analysis application for checking on functioning Belgrade gas distribution system.

Key words: *. Risk analysis, Natural gas, Gasification, Consumption.*

Apstrakt: *Cilj rada je da se prikaže primena analize rizika u određivanju optimalnih parametara rada gasovodnog sistema. Tokom funkcionisanja gasovodnog sistema povećanje potrošnje gasa od strane jednog potrošača direktno se odražava na ostale potrošače. Određivanje promene potrošnje primenom klasičnih metoda, pri izračunavanja pada pritiska kao diskretnih promenljivih za definisanje promene potrošnje potrošača predstavlja veoma kompleksan problem. Zbog toga je veoma teško dobiti sliku o ponašanju gasovodnog sistema. Primenom analize rizika, rešenje problema se pojednostavljuje i metoda simulacije je veoma korisna za predviđanje ekscesnih situacija. Promena potrošnje gasa definisana je funkcijom raspodele sa odgovarajućim opsegom promene. Simulacija rizika se može izvesti primenom metode Monte Carlo ili Latin Hypercube. Kao rezultat simulacije dobija se grafik raspodele verovatnoće posmatrane promenljive, koji omogućava donosiocu odluke da lako upravlja i kontroliše ponašanje gasovodnog sistema.*

U radu se prikazuju glavne karakteritike za ocenu rizika. Takođe, prikazuje se primena analize rizika u cilju provere funkcionisanja distributivne mreže Beograda.

Ključne reči: *Analiza rizika, prirodni gas, gasifikacija, potrošnja*

1. INTRODUCTION

During gas pipeline system functioning in certain situation it is coming to gas consumption increase by each consumer, what is directly reflecting on other consumers.

The aim of this paper is to present the use of Risk Analysis in gas pipeline system for improving its working performance. Providing consumption as a variable use of classical method, which calculates the pressure drop in discrete manner for defined gas consumption change by individual consumers or consumer centers, it is very difficult to obtain presentation about gas pipeline system behavior. By application of Risk Analysis the solution of problem is simple and of better quality and as simulation method is very useful in accident situation. Gas consumption change is defined by function with adequate change range. Using methods Monte Carlo or Latin Hypercube with a high number of iteration gas pipeline system behavior simulation is done, which is equivalent to thousand and thousand combination using classical method. As a result of Risk Analysis graph of probability distribution is obtained, which is useful to decision maker for gas consumption control. [1]

2. RISK ANALYSIS AND RISK QUANTIFICATION

Risk analysis, in its broadest form, includes problem identification, specification of objective and constraints, modeling, uncertainty analysis, sensitivity analysis, and rules that lead to a decision. Generally speaking, risk analysis and assessment refer to the quantification of uncertainty, almost always in the context of possible investments. In the oil and gas business, allthought much of the analysis might pertain to reserve size, capital cost, production forecasting, the bottom line universally is monetary value.

The concept of risk comes about due to our recognition of future uncertainty, our inability to know what the future will bring in response to a given action today. Risk implies that a given action has more than one possible outcome. [2,3,4]

Gas system function is related to certain risk. Somewhere in between, actions pass from being

1. UVOD

Prilikom funkcionisasnja gasovodnog sistema u određenim situacijama dolazi do povećanja potrošnje gasa od strane pojedinih potrošača, što se direktno odražava na ostale potrošače.

Klasičan postupak simulacije ponašanja gasovodnog sistema podrazumeva proveru padova pritisaka za diskretno definisane promene potrošnje gasa od strane pojedinih potrošača ili potrošačkih centara. Imajući u vidu da je potrošnja gasa promenljiva, klasičnim postupkom simulacije veoma je teško dobiti sliku o ponašanju gasovodnog sistema. Primenom analize rizika stvar se znatno pojednostavljuje a kvalitativno poboljšava. Promena potrošnje gasa se definiše preko funkcija u odgovarajućem opsegu promena. Analiza rizika simulaciju ponašanja gasovodnog sistema izvodi preko metode Monte Carlo ili Latin Hypercube sa velikim brojem iteracija. To je isti kao da se klasičnim postupkom izvodi hiljade i hiljade šta ako kombinacija. Kao rezultat rizik analize dobija se grafik raspodele verovatnoće potrošnje gasa što donosiocu odluke znatno olakšava regulisanje potrošnje. Analiza rizika posebno omogućava simulaciju ponašanja gasovodnog sistema u određenim kriznim situacijama, bilo da se radi o havarijama ili o smanjenoj isporuci gasa. U radu se prikazuje primena analize rizika u gasovodnom sistemu u cilju njegovog efikasnijeg funkcionisanja.[1]

2. ANALIZA I KVANTIFIKACIJA RIZIKA

Analiza rizika obuhvata identifikaciju problema i specifikaciju ciljeva i ogreničenja, modeliranje, analzu nesigurnosti, analizu osetljivosti, kao i pravila koja dovode do odluke. U naftnoj i gasnoj privredi, iako se mnoge analize odnose na rezerve, kapitalne troškove, predviđenje proizvodnje i slično, krajnji parametar je uvek ostavrena dobit, odnosno profit.

Koncept rizika se poklapa sa sa našim shvatanjem buduće neizvesnosti, odnosno našom nemogućnošću da se sazna šta će doneti budućnost kao odgovor na sadašnju akciju. [2,3,4]

Funkcionisanje gasovodnog sistema je uvek vezano sa određenim stepenom rizika. Obično nonrisky to risky. This distinction, although vague, is important if you judge that a simulation is risky, risk becomes on criteria for deciding what course of acton you should purse.

The first step in risk analysis is recognised need for it. Is there significant risk involved in the situation you are interested? Realising that you have a risky situation is only the first step. How do you quantify the risk you identified for a given uncertain situation? Quantifying risk means determining all the possible values a risky variable could take and determining the relative likelihood of each value. [5]

For example, we can make a question what is the probability that one consumer will be supplied with gas in that way that its functioning is not damaged by changes in gas consumption.

Process of risk quantifying consisting of:

- Problem analysis and model defining
- Simulation
- Making a decision and interpretion of results

2.1 Problem analysis and model defining

The concrete problem must be analyzed and make model of their behavior. We have to consider every action flow and all possibly options step by step. Following considerable flow problem is analyzed every action from risk aspect, ranged by their relative significance and selected risk control alternative. On that basis the installed model can use some method for simulation.

2.2. Simulation

Simulation in this sense refers to a method where the distribution of possible outcomes is generated by letting a computer recalculate variables in model over and over again, each time using different randomly selected sets of values for the probability distribution. In effect, the computer is trying all valid combinations of the values of input variables to simulate all possible outcomes. This is just as if you can run hundreds or thousands of "what-if" analyses on variables in model. Today are mostly used Monte Karlo and Latin Hypercube method for randomly selected sets of values.

negde na sredini, akcije prelaze iz nerizičnih u rizične. Ova razlika, iako neodređena, važna je ako se proceni da je situacija rizična, jer u tom slučaju rizik postaje kriterijum za odlučivanje koji pravac akcije treba slediti.

Prvi korak u oceni rizika je spoznavanje potrebe za tim. Da li je značajan rizik uključen u situaciju koja se razmatra? Shvatanje da postoji rizična situacija je samo prvi korak. Kako kvantificirati rizik koji je identifikovan za datu situaciju? "Kvantificiranje rizika" znači određivanje svih mogućih vrednosti koje rizična promenljiva može imati i određivanje relativne verovatnoće svake vrednosti. [5]

Na primer, može se postaviti pitanje koja je verovatnoća da neki potrošač bude sigurno snabdeven gasom, tako da promene u potrošnji gasa od strene drugih potrošača ne mogu ugroziti njegov rad.

Postupak ocene rizika sastoji se od:

- Analize konkretnog problema i definisanja modela
- Simulacije
- Donošenje odluke-interpretacija rezultata

2.1 Analiziranje problema i definisanje modela

Da bi se mogla primeniti simulacija u cilju ocene rizika konkretan problem se mora detaljno sagledati i analizirati. Iz tog razloga potrebno je postaviti model ponašanja razmatranog problema. Korak po korak se mora predvideti tok svake akcije kao i sve moguće opcije. Na bazi postavljenog modela primenjuje se neka od metoda simulacije za ocenu rizika.

2.2. Simulacija

Simulacija ima zadatak da primenom odgovarajuće metode generiše raspodelu mogućih izlaznih promenljivih tako što program, iterativnim postupkom, svaki put koristi različite slučajno odabrane nizove vrednosti za raspodelu verovatnoće ulaznih promenljivih. Praktično, kompjuter traži sve kombinacije ulaznih promenljivih simulirajući sve moguće slučajeve. To je isto kao kada bi se izvodilo stotine ili hiljade "šta - ako" analiza. Danas se najviše primenjuju Monte Karlo i Latin Hypercnbe metode uzorkovanja.

2.3. Making a decision and interpretion of results

Decision-maker must interpret given results of simulation and on that basis make decision about possibly risk. Result interpretation can be achieved in two ways.

Interpreting a Traditional analysis Most decision makers compare the expected results to some standard or minimum acceptable value. If it is at least as good as the standard, they find the result acceptable. But, most decision-makers recognize that the expected result does not show the impacts of uncertainty. They have somehow manipulate the expected result to make some allowance for risk. They might arbitrarily raise the minimum acceptable result, or they might non rigorously weight the chance that the actual result exceed or fall short of the expected result. At best, the analysis might be extended to include several other results, such as "worst case" and "best case" in addition to the expected value. The decision maker than decides if the expected and "best case" values are good enough to outweigh the "worse case" value.

Interpreting risk analysis Risk analysis results are presented in the form of probability distributions. The decision-maker must interpret these probability distributions, and make a decision based on the interpretation.

In risk analysis, the output probability distributions give the decision-maker a complete picture of all the possible outcomes. This is a tremendous elaboration on the "worst-expected-best" case traditional approach. As a result, you no longer just compare desirable outcomes with undesirable outcomes. Instead, you can recognize that some outcomes are more likely to occur than others, and should be given more weight in your evaluation. This process also is a lot easier to understand than the traditional analysis because a probability distribution is a graph. You can see the probabilities and get proper feeling for the risks involved.

2.4. Sensitivity analysis results

The main characteristic of risk analysis is enabling sensitivity analysis results. This identifies the most critical inputs in analysed model. Sensitivity analysis results are shown on tornado graphic. Sensitivity analyses performed

2.3. Donošenje odluke-interpretacija rezultata

Donosioc odluke mora da interpretira dobijene rezultate simulacije i da na osnovu njih donese odluku o mogućem stepenu rizika. Interpretacija rezultata može se obaviti na dva načina.

Klasičan postupak interpretacije. Kod klasične analize rizika dobijeni rezultati se interpretiraju pojedinačno. Donosilac odluke upoređuje očekivani rezultat sa nekom standardnom ili minimalno prihvatljivom vrednošću i donosi odluku da li je taj rezultat prihvatljiv u granicama zadate tačnosti. Međutim, većina donosilaca odluke prihvata da očekivani rezultat ne pokazuje uticaj neodređenosti. Takođe, može se definisati minimalno prihvatljiv rezultat ili se mogu definisati granice unutar kojih se on mora nalaziti. U najboljem slučaju analize se mogu proširiti tako da uključe nekoliko drugih rezultata kao što je "najgora vrednost" i "najbolja vrednost" u nastavku do očekivane vrednosti. Donosilac odluke onda odlučuje da li su očekivana i "najbolja " vrednosti dovoljno dobre da pretegnu vrednost "najgore".

Postupak interperatcije baziran na analizi rizika. Rezultati analize rizika prikazani su preko garfika raspodele verovatnoće. Donosilac odluke može interpretirati raspodelu verovatnoće i doneti odluku na bazi nje.

U analizi rizika, izlazna raspodela verovatnoće daje donosiocu odluke kopmletnu sliku svih mogućih izlaza. U odnosu na klasičan postupak više se ne porede željeni izlazi sa neželjenim. Umesto toga, na osnovu izlazne raspodele verovatnoće, može se prepoznati da li će se neki izlazi pojaviti pre drugih i u tom slučaju im se dati veća težina u proceni. Ovakav pristup je lakši u odnosu na klasičan zato što su izlazni parametri prikazani u obliku raspodele verovatnoće, sa koje se direktno vidi verovatnoća njihovog pojavljivanja kao i mogući rizik. Ovo donosiocu odluke znatno olakšava posao i smanjuje mogućnost greške u oceni rizika.

2.4. Analiza osetljivosti rezultata

Jedna od vrlo važnih karakteristika analize rizika je da omogućava obavljanje analize osetljivosti rezultata. Analiza osetljivosti pokazuje osetljivost svake izlazne promenljive u funkciji ulazne raspodele. Rezultati analize osetljivosti su prikazani na tornado garfiku.

on the output variables and their associated inputs use either multivariate stepwise or rang order correlation. [6]

Analiza osetljivisti se vrši na izlaznim promenljivim i njihovom povezivanju sa ulaznim promenljivima primenom višestruke regresije ili koeralcije poretka. [6]

3. RISK ANALYSIS APPLICATION

3. PRIMENA RIZIK ANALIZE

Risk Analysis application will be shown on function part example of Belgrade gas distribution pipeline system. The main characteristic of this gas distribution system is that it supplies eight heat plants. These consumers, especially starting their consumption in morning hours, can seriously damage other consumers supplying with natural gas. This situation is expressed nowadays, as in the past, because deliveries of gas do not cover needs.

Primena analize rizika prikazaće se na primeru funkcionisanja dela gasovodne mreže Beograda. Za ovaj deo gasovodne mreže Beograda karakteristično je da snabdeva osam toplana. Ovi potrošači, naročito pri njihovom startovanju u jutarnjim časovima kao i radu pri niskim temperaturama ozbiljno mogu ugroziti snabdevanje drugih potrošača prirodnim gasom. Situacija je posebno izražena danas, kao i u proteklom periodu, zbog nedovoljnih isporuka gasom.

Outcome pressure values of Cerak main measure and regulation station -"MMRS" is 6.5-7 bar, and of Avala "GMRS" is 13 bar to heat plant (HP) Vozdovac; after that is reduced to 7 bar. At figure 1. is shown gas distribution system of Belgrade. Average consumption of gas at temperature of -14°C is shown in Table 1.

Izlani pritisak iz GMRS Cerak iznosi 6.5-7 bar (aps), dok je iz GMRS Avala 13 bar do toplane Voždovac, nakon čega se redukuje na vrednost pritiska 7 bar. Gasovodna mreža Beograda šematski je prikazna na slici 1. Prosečna potrošnja potrošača na ovom delu gasovodne mreže, pri temperaturi od -14°C prikazana je u Tabeli 1.

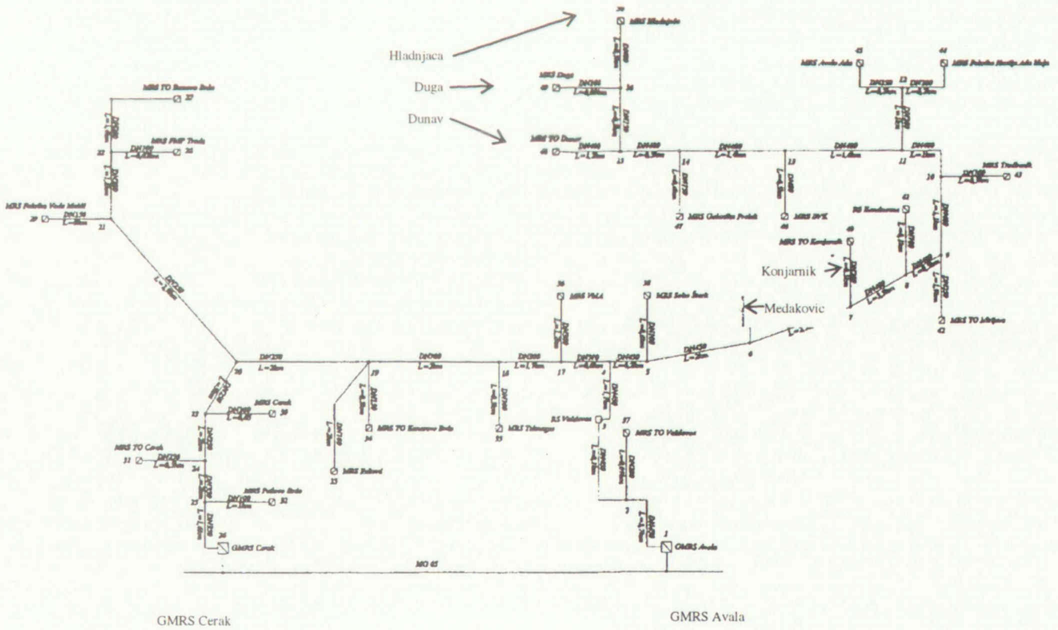


Figure 1 Gas distribution system of Belgrade
slika 1 Gasovodna mreža Beograda

In this example is analyzed influence of gas consumption increase by consumers which are nearer to "GMRS" Cerak on other ones which are situated at the end of network. Concretely it is analyzed the influence of increased consumption HP Medakovic and HP Konjarnik. Consumption change is analyzed in range 1000-4000 m^3/h for

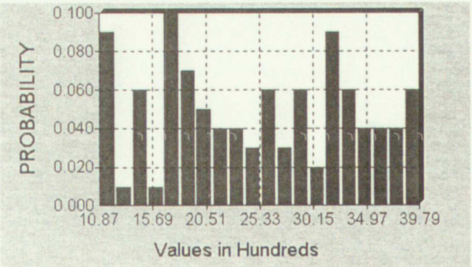
U ovom primeru analiziran je uticaj kako se povećana potrošnja gasa potrošača koji su bliži GMRS Cerak odražava na potrošače koji se nalaze na kraju mreže. Konkretno analiziran je uticaj povećane potrošnje TO Medaković i TO Konjarnik. Promena potrošnje je analizirana u opsegu 1000-4000 m^3/h za TO Medaković i

HP Medakovic and 6000-12500 m^3/h for HP Konjarnik. Probabilities of consumption change are generated by risk analysis and presented on figures 2.

6000-12500 m^3/h za TO Konjarnik. Primenom analize rizika generisane su verovatnoće potrošnje gasa u TO Medaković i TO Konjarnik, slika 2.

Table 1. Consumption of gas at temperature of -14°C [6]
Tabela 1. Potrošnja gasa na temperturi od -14°C[6]

Measure and regulation station (MRS)	Capacity (m^3/h)	Minimal income pressure at MRS (bar)
Petlovo brdo (com. consumption)	1000	1.63
HP Cerak	10500	4.13
Cerak (com. consumption)	100	6.00
Makis	100	2.88
FMP Trade	150	4.13
HP Banovo brdo	5400	4.13
HP Vozdovac	6000	4.13
Vozdovac (com. consumption)	0	6.00
VMA	6000	3.50
Tehnogas	250	2.88
Rekord	3600	2.88
HP Kanarevo brdo	3100	4.13
Soko Stark	500	2.88
HP Medakovic	2500	3.50
HP Konjarnik	9250	4.13
Karaburma (com. consumption)	100	6.00
HP Mirijevo	3800	3.50
Trudbenik	900	4.13
Paper factory Ada Huja	3000	2.25
Avala Ada	600	4.13
BVK	1200	2.88
Galenika prolek	400	3.50
HP Dunav	17000	4.13
Duga	800	2.88
Hladnjaca	150	2.88



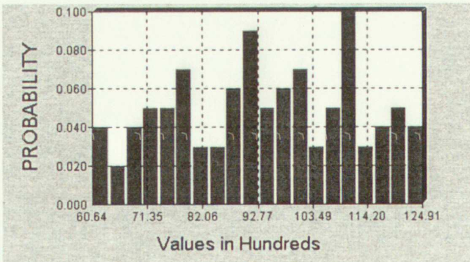


Figure 2 Consumption change in HP Medakovic and Konjarnik
slika 2 Promena potrošnje u TO Medaković i TO Konjarnik

The influence of consumption change in HP Medakovic and HP Konjarnik is analyzed on HP Dunav, Duge and Hladnjace. The value of income pressure at "MRS" HP Dunav, Dugu and Hladnjacu is taken as criteria. In table 1 are shown minimal income pressure at "MRS" which have values 4.13, 2.88 and 2.88 bar respectively.

Uticaj promene potrošnje u TO Medaković i TO Konjarnik analiziran je na funkcionisanje TO Dunav, Duge i Hladnjače, odnosno kako će se povećanja potrošnja odraziti na njihovo snabdevanje gasom. Kao kriterijum posmatrana je vrednost ulaznog pritiska u MRS TO Dunav, Dugu i Hladnjaču. Iz tabele 1 se vidi da minimalni ulazni pritisci u gasovodu moraju iznositi 4.13, 2.88 i 2.88 bar respektivno.

Probabilities of pressure distribution for HP Dunav, Dugu and Hladnjacu are generated for analyzed consumption change and presented on figures 3. and 4. On the basis of calculated pressures figure 2 and 3, we can clearly notice that analyzed consumption change in HP Medakovic and HP Konjarnik can not damage functioning of HP Dunav, Duge and Hladnjace.

Za analiziranu promenu potrošnje generisane su verovatnoće raspodele pritisaka za TO Dunav, Dugu i Hladnjaču, slika 3 i 4. Na osnovu izračunatih pritisaka, slike 3 i 4, jasno se vidi da analizirana promena potrošnje gasa u TO Medaković i To Konjarnik ne može da ugrozi funkcionisanje TO Dunav, Duge i Hladnjače.

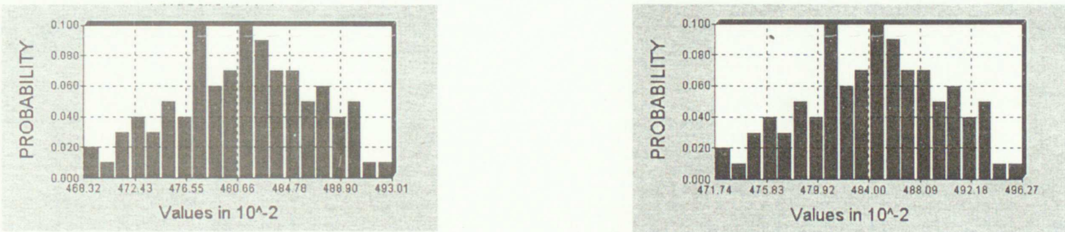


Figure 3. Pressure probability distribution in HP Dunav and Duga
slika 3. Verovatnoća raspodele pritiska u TO Dunav i Dugi

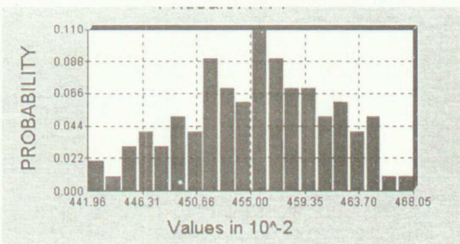


Figure 4 Pressure probability distribution in Hladnjaca
slika 4. Verovatnoća raspodele pritiska u Hladnjači

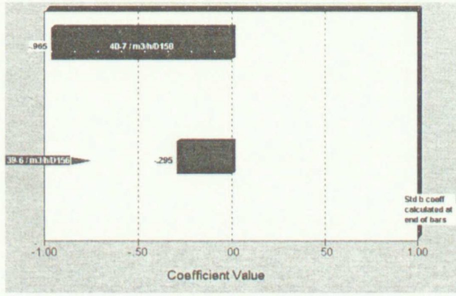


Figure 5. Sensitivity analysis
slika 5 Analiza osetljivosti

Also, it is conducted the analysis of gas consumption change sensitivity in HP Medakovic and HP Konjarnik to see the influence of each one. Regression sensitivity results given at figure 5 shows that consumption changes in considerable range and it has influence on gas pipeline system functioning.

Takođe je izvršena i analiza osetljivosti promene potrošnje gasa u TO Medaković i TO Konjarnik da bi se videlo kakav je njihov pojedinačni uticaj, promene potrošnje u razmatranom opsegu, na funkcionisanje gasovodnog sistema, slika 5. Sa slike se jasno vidi da TO Konjarnik ima znatno veći uticaj na ponašanje gasovodnog sistema.

4. CONCLUSION

This techniques are tools that can be used to help make decisions and arrive to the solutions. Like the tools, they can be used to bring good advantage for skilled practitians, or they can be used to create havoc in the hands of the unskilled. Finally, you should recognize that risk analysis can not guarantee that the action you choose to follow, even if skillfully chosen, to suit your personal preferences, is the best action viewed from the perspective of hindsight. You can be guaranteed that you have chosen the best personal strategy given the information that is available to you.

4. ZAKLJUČAK

Lično donošenje odluka može biti individualno, nedosledno, neodređeno, subjektivno ili pod uticajem ličnih emocija i drugih faktora, kao što je na primer politika. Analiza rizika obezbeđuje više dodatnih informacija za donošenje odluke. Zbog toga donesene odluke na bazi analize rizika su objektivne, odgovarajuće i realne. Analiza rizika smanjuje uticaj lične greške i promoviše timski rad. Najvažnije, analiza rizika može preventivno pomoći sprečavanju katastrofalnih gubitaka prouzrokovanih čovekovom greškom u odlučivanju. Analiza rizika veoma uspešno omogućava određivanje optimalnih parametara rada gasovodnog sistema.

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