ISSN 1392−1207. MECHANIKA. 2014 Volume 20(5): 512−515

Functioning analysis of cathode protection of pipelines for transporting of natural gas through fuzzy logic

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crossref http://dx.doi.org/10.5755/j01.mech.20.5.6144

1. Introduction

Once with development of oil and gases industries, it was conditioning also the necessity to create a hydrocarbons which to be performed in safety conditions and with the possibility to seize, detect damage, respectively of accidental leakages. Especially for long pipelines which pass near to urban areas or through farmlands is necessary to exist a cathode protection system and/or an analysis method both of cathode protection parameters as of transporting, by following the parameters: pressure, flow, density, temperature, transporting speed etc. The purpose of this controlling and informational acquisition system – through which is following the electrical potential pipeline – sol, flows evolutions of the receiving-deliveries process is to ensure, in safety conditions, the transporting process of natural gases to consumers [1].

To prevent any accidental leakages of natural gases, and thus occurrence of certain corrosions, cracks on the pipeline route have developed numerous monitoring methods, analysis, in by dispatching as meticulous of transporting parameters. In this sense was search a procedure, an algorithm through would increase the detection accuracy of the defect, and no least to reduce the detection time of the defect. In practice it is a very delicate issue to diagnose the corrosion defects and also their location in the field [2].

They are different available methods to detect and locate the leakages at the pipelines, which we propose is about the analysis of electrical potential of the pipeline beside the ground. This method is conditioned by the necessity to install potential sockets along to the pipeline. It is a method through which are sequentially following the evolution of cathode protection parameters, following that by notification an anomaly – decreasing the electrical potential under the value to which ensure the cathode protection – to determine the defect location.

Because of complexity of diagnose of operation of cathode protection, on the long pipelines, a one method is not enough to analyse of qualitative operation of cathode protection.

However, was a result in a combination of methods, heuristic, to solve this issue. This paper proposes a monitoring method of cathode protection by using of fuzzy decision theory.

2. Control of pipe protection by DVG method

With direct current voltage gradient (DCVG) equipment can be make an inspection concerning the integrity of cathode protection grounded. The technology of this method is characterised by investing the wide applications on the inspection activity and quality analysis of cathode protection of pipelines. This is one of the newest and more precise to detect the insulation defects. This method measure with accuracy continuous current potential gradients in the mode ON – OFF being capable to determine the location, severity, the corrosive character or non-corrosive of the defects and also the possible presence of stray currents [3].

The method is based on measurement of difference of potential between two points along of the pipeline, measured potential at the ground surface. When a continuous current is applied to a metallic pipeline grounded in a same way as the cathode protection, this current pass through the ground in the places where exist direct contact, meaning without insulation or damaged. In the defect places, as the current is higher, as the defect is much higher [4].

The current is injected on the pipeline and can be supplied by the cathode protection station or by a mobile station. The signal of continuous current is pulsating, achieving of this signal performing by installation on the electrical circuit of cathode protection station of one cyclic switch with a period of 0.3 s on the ON position and 0.7 s on the OFF position.

To evidence the potential gradient on the ground, this method use a special voltmeter, ultrasensitive, which measure the potential difference between two un-polarized electrodes of $Cu/CuSO_4$ placed over the pipeline on the ground at a distance of approximately by 1,5 – 2 m one side by other along of the pipeline.

As the operator is passing along of the pipeline, in the moment when occur a potential difference between the two electrodes, this is associated on the device's scale with a regular motion of needle (from the analogical voltmeter from equipment configuration) which correspond with the current's pulse. The short motion of the needle the direction towards which the defect is finds.

The operator motion is continuous, and when is exceeding the defect area, the needle will change its direction [4].

The withdrawal of two electrodes can touch the place where the needle of the voltmeter is no longer move. In this case the defect is positioned at the middle of distance between the two electrodes.

The location where are intersected the medians of the segments between of two electrodes after the two directions, is the exactly positioning of the defect on the pipe-

Fig. 1 Inspection on the pipeline route DCVG method [7]

line [5], [6].

The position of the determinate defects on the pipeline route will be recorded with the aid of GPS.

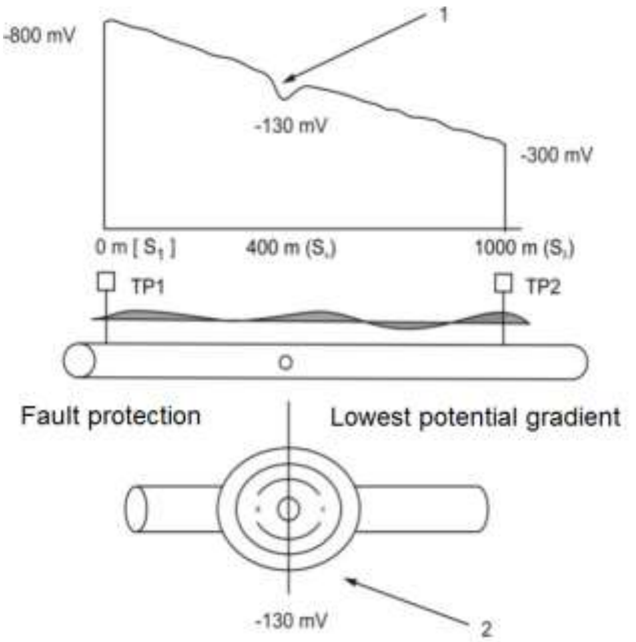

Fig. 2 The situation of potential gradient on pipeline: *1* – defect potential, *2* – equipotential lines

In establishing of reparation priority of the insulation defects are taken in consideration several factors from which the main are: the size of defect (% IR), the nature of defect:

$$IR\% = \frac{E_{mr} \cdot 100}{E_{cr}}, \tag{1}$$

$$E_{cre} = S_1 - \frac{d_x\left(S_1 - S_2\right)}{D_2 - D_1}, \tag{2}$$

where S_1 is the potential of upstream plug (Fig. 2, $S_1 = -800\ \text{mV}$); S_2 is the potential of upstream plug ($S_2 = -300\ \text{mV}$); d_x is the potential of upstream plug; ($d_x = -400\ \text{mV}$); D_1 is position of the downstream plug; ($D_1 = 0\ \text{m}$); D_2 is position of the upstream plug; ($D_2 = 1000\ \text{m}$); E_{mre} is potential measured on the defect point (on pipeline), mV; E_{cre} is potential measured on the defect point, mV (rel. 2).

The classification after strictness (size) of defects dependent by % IR is:

a. 0 – 15% IR Small defects;
b. 15 – 35% IR Medium defects;
c. 35 – 70% IR Large defects;
d. 70 – 100% IR Very large defects [3].

3. Localization of accidental damages by decisions fuzzy method

The logic fuzzy introduced by Lotfi Zadeh in 1965, represent an surplus set of conventional Boolean logic, logic which was extend to contain the concept of partial true – values of the truth ranged between “complete truth” and “complete false”.

The basic structure of fuzzy method to take the decisions, proposed to locate of accidental leakage point is illustrated in Fig. 3. To detect a state of insulation defect, corrosion, of an accidental fluid leakage, the input dates must be transformed into fuzzy qualitative through the fusification process. There are a various options for the belonging functions, for example, triangle, Gaussian form and exponential functions.

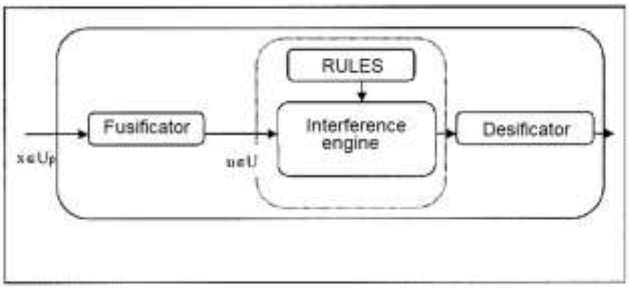

Fig. 3 The localization structure with method of taken of fuzzy decisions

In Fig. 3 is represented a classic structure of a fuzzy system compound by four basic components: fusificator, rules, interference engine, desificator. After the rules was considered, the fuzzy system can be watch as a transforming input – output, quantitative expressible in the form $y = f\left(x\right)$. With the aid of the rules prepared by experts are expressed by diagnose propositions. In this sense the form of diagnose fuzzy rule R_i is:

*R_i : **IF** the state of cathodic protection of transporting pipeline is characterised by a potential $E\left(mV\right)$ **AND** E is very low **THEN** the results argument for the state of pipeline insulation is with defect.*

A distinctive feature of fuzzy system is the fact that the lexical knowledge and the numerical dates can be simultaneous controlled. Practical, this represents a nonlinear transformation applied to the vector of input data by a scalar output.

In this sense, starting from the fuzzy role, constructed above, are put it in evidence certain observations:

- transforming of linguistic variables in numerical correspondence which means a large number of values;
- the linguistic variables each have a infinite range of terms;
- the logical connections of linguistic variables are type: AND, OR.

The fusificator is have the role to implement the numerical expressions into fuzzy sets, required for the activation of rules, which in turn have associate to the linguistic corresponding values fuzzy sets.

The interference engine applies a transformation of rules sets into fuzzy sets. It is implemented a processing module of the rules.

In general, it is necessary a mutual transformation from fuzzy sets to the numerical values that task is having the fusificator [8].

4. Monitoring of cathodic protection of transporting pipeline by fuzzy logic using the MATLAB 7.9.0 software

Accidental leakages of natural gases are an explosive medium and which is not lacking only the trigger source to an event, explosion, and fire to produce it. A possibility to implement the fuzzy logic is provided by the MATLAB software, in this sense by the "Fuzzy toolbox" module, it was create an application, simple, through which was establish 12 analysis rules (Figs. 4 and 5). To the program was define the input and output variables and was establishing the general form of appertain functions: for the continuous tension injection, of cathodic protection, and for the pipeline – ground potential: Gaussian function (gaussmf), for injection continuous current and for defect severity %IR: triangular function (trimf). After establishing of speech environment and of defining parameters further is editing the rules base for the fuzzy system. In the example presented we have three input variables and one output variable.

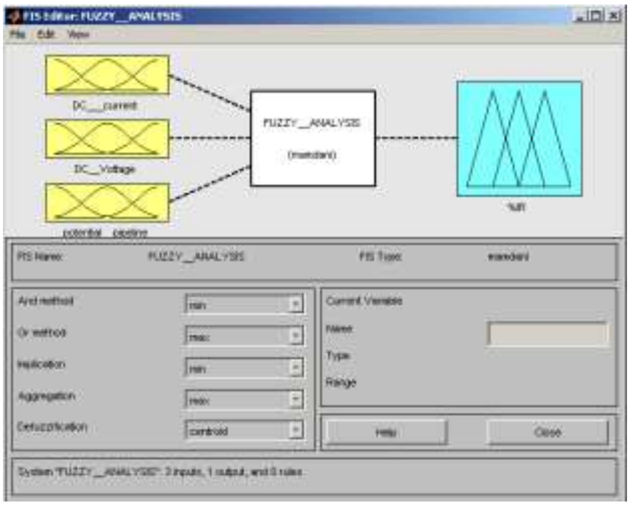

Fig. 4 The "Fuzzy interference system" editor

The input variables are: continuous current $I_{cc}(A)$, continuous tension (V), potential pipeline-ground (mV) which are under incidence of condition "IF" again input-output. In AND the output variables are under condition "THEN". Through logical connectors can be made the combination in this case at the construction of the three rules, was used the variables connector.

In the present case having three input variables, the injection current, continous curent, A; voltage continous curent, V; the pipeline-sol potential, mV and one of output IR% − the relative severity of protection defect. After designing of input and output variables are defined the appartanence functions and the speech univers for each variable.

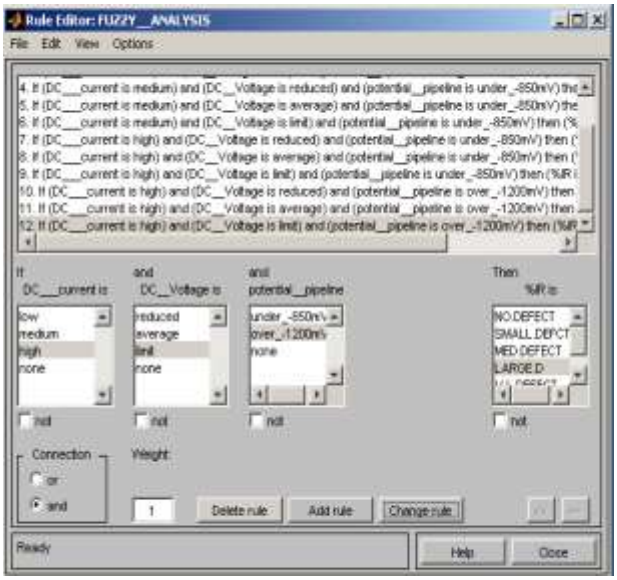

Fig. 5 The rules editor

By establishing of twelve rules that describe the interference process, must be mentioned that in the case where a rule has a higher weight than the other rules which are in the process it shall be specified in the *weight* box. This weight is marked in the parenthesis on each rule. After the rules construction, the knowledge base is automatically connected to the system being able the possibility to be visualise graphic the interference based on the fuzzy logic (Fig. 6).

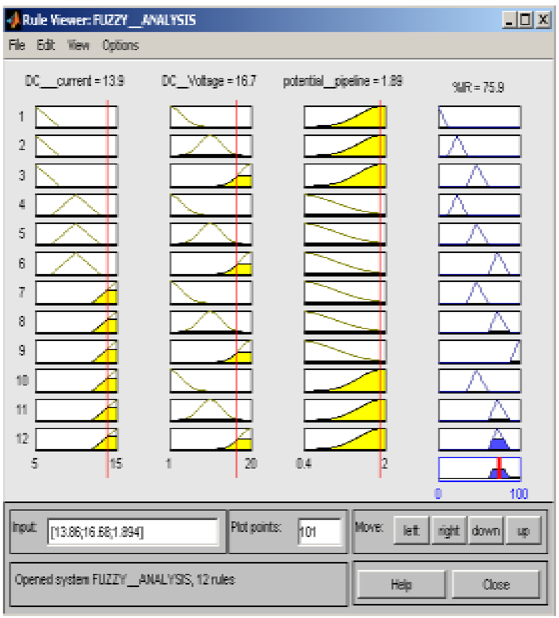

Fig. 6 Visualisation of the rules

The fusification operation, the rules visualisation transform the input sizes into a singleton fuzzy size (crisp). The red riglet, by translation it is that create the analysis of the values between two values from the absice.

5. Conclusions

By using of locating method of insulation defects, is preventing the occurring of accidental corrosion and in this case prevention of natural gases (hydrocarbons) leakages from the pipeline, in the environment through DCVG method. The advantage of using of this method, of fuzzy decisions, in the analysis of cathodic parameters (continuous voltage, continuous current and pipe-ground potential), prevent the accidental occurs of sealing defects of the metallic structure of the transporting pipelines of natural gases, monitoring the risk of apparition of dangerous occurrence such as: explosions, fires.

The fuzzy logic through the MATLAB software provide a perspective concerning the performance increase from qualitative point of view to transport natural gases, and also to monitoring of cathodic protection by SCADA.

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GAMTINIŲ DUJŲ VAMZDYNŲ KATODINĖS APSAUGOS FUNKCINĖ ANALIZĖ TAIKANT “FUZZY“ LOGIKĄ

R e z i u m ė

Katodinė apsauga naudojama užkirsti kelią atsitiktiniams pažeidimams ir nutekėjimams sukeltiems transportinių vamzdynų metalo konstrukcijų korozijos. Tinkamas katodinės apsaugos sistemos funkcionavimas yra sekamas atliekant pagrindinių parametrų monitoringą: tikrinant elektrinį potencialą tarp vamzdyno ir grunto, įpurškimo parametrus (pastovi įtampa, pastovi srovė), atitinkamai matuojant vamzdyno izoliacinę varžą.

Atliekant SCADA (supervisory control and data acquisition) parametrų monitoringą konstatuojamas faktas, kad sumažėja atsitiktiniai dujų nuotėkiai dėka korozijos poveikių panaikinimo angliavandeniams patenkant į aplinką. Šiame straipsnyje pateikiamas analizės metodas įvertinantis katodinės apsaugos poveikį, DCVG (Direct Current Voltage Gradient) metodas sąveikavo kartu su “fuzzy” analizės metodu, kurio pagalba vienu metu buvo operuojama skaitmeniniais duomenimis ir leksikos argumentais, svarbiais identifikuojant pažeidimų vietą.

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FUNCTIONING ANALYSIS OF CATHODE PROTECTION OF PIPELINES FOR TRANSPORTING OF NATURAL GAS THROUGH FUZZY LOGIC

S u m m a r y

The cathodic protection is used to prevent the occurrence of accidental damages, leaks, generated by the corrosion of metallic structure of tubular material of transporting pipelines. Following the proper functioning of the cathodic protection system is made by monitorize of the main parameters: electrical potential pipeline-ground, injection parameters (continuous voltage, continuous current), respectively by measurement of insulating resistance of pipeline.

In the case of monitoring of parameters by SCADA, it is constate the fact that are reduce the accidental gases leakeges, generated by corrosion avoid the impact which is produced by the evacuation of hydrocarbons on the envirnment. In this paper is presented an analysis method regarding the functioning of the cathodic protection, the DCVG method coloborated with a fuzzy analysis method, trough which are simultanely operated either the numerical dates, and lexical arguments, prior to locate, in the field, more precisely of the damage.

Keywords: cathodic protection, key parameters, corrosion, natural gases, fuzzy.

Received January 08, 2014
Accepted August 20, 2014