Improving Interrupter Synchronization in CIPS Cathodic Protection Test for Gas Transmission Pipelines

Majid Nosuhi[1*], Mohsen Ashourian[2], Hamid Nazemy[3]
1- Department of Electrical Engineering, Majlesi Branch, Islamic Azad University, Majlesi, Iran.
Email: m94nosoohi@gmail.com (Corresponding Author)
2- Department of Electrical Engineering, Majlesi Branch, Islamic Azad University, Majlesi, Iran.
Email:ashourian@iaumajlesi.ac.ir
3- Department of Metallurgy Engineering, Majlesi Branch, Islamic Azad University, Majlesi, Iran.
Email:hamidnazemy@yahoo.com

Received: July 2019 Revised: September 2019 Accepted: November 2019

ABSTRACT:
Corrosion is one of the most important problems which underground gas pipelines is facing it. Cathodic protection systems are dynamic systems that use electrical current to control corrosion. According to the existing standards there are different methods for evaluating level of cathodic protection and coverings underground metal pipes. One of the most practical methods is the close interval potential survey (CIPS).The efficiency of this method is very dependent on the quality of measuring parameter during the inspection. minimising all the error source , either during the inspection or when interpreting the data is vital. In this research CIPS method is analyzed and by optimizing synchronization of the Interrupter devices to decrease the errors during the CIPS test, in evaluating of cothodic protection level and covering the gas transmission underground metal pipes provides a significant improvement.

KEYWORDS: Cathodic protecticn, CIPS, GPS, Interrupter.

1. INTRODUCTION

Iran has the second largest natural gas fields in the world with 27 trillion cubic meters of world's total reserves. A major portion of these gas fields are in south of Iran and along the Persian Gulf. Gas pipelines are buried in the ground and transmit gas through a state-wide distribution system. Corrosion is one of the serious challenges in such systems which can lead to severe and costly damages and disturbances in the gas distribution system, if not protected properly. Thus, corrosion and gas pipeline protection are important challenges which Iran Gas Transmission Co. is faced [1].

In order to evaluate their performance, the cathodic protection systems are constantly monitored, so that the inefficient performance parameters can be identified and the corrosion can be prevented before any serious structural damages. There are different approaches to monitor a cathodic protection system. Close interval potential surveys (CIPS) is one of the most practical approaches. Efficiency of this approach highly depends on survey measurement quality during inspection. Therefore, it is vital to minimize all error sources in both inspection and data interpretation. In this study, interrupter performance in CIPS is analyzed to make us able to improve evaluation parameters of cathodic protection level using GPS technology [2].

During CIPS tests, three rectifier transformer are switched ON and OFF intermittently. During walking on the ground and above the pipeline, the potential difference between pipeline and ground is measured and recorded through test points during ON and OFF mode of transformer. Analyzing the measurements provides us with useful information about cathodic protection level in different locations which lead to future actions for improving cathodic protection and corrosion prevention. The main problem in this study is the precise timing of rectifier transformers' ON and OFF mode in CIPS test which have a crucial effect on eliminating measurement errors in measuring the potential difference between pipeline and ground. Therefore, interrupters which could switch ON and OFF the transformers synchronously are crucially effective in achieving real results. In this study, an interrupter device is built and the device performance in evaluating cathodic protection level of a real gas pipeline is tested. The interrupters are synchronized using GPS technology [3].

This paper consists of five sections. After abstract and introduction, a brief literature review is presented. Then, the details of how to improve synchronization, how to build synchronized interrupters using GPS technology and how to use them in CIPS tests are discussed. In the fourth section, CIPS test results using innovative synchronizing interrupters performed on a real gas pipeline are presented. Finally, the results are compared and a conclusion and some suggestions are made.

2. LITERATURE REVIEW

- There are different ways to evaluate buried pipeline coating and the influence of cathodic protection on the pipeline, based on available standards. Some of them are listed below:
- Measuring the coating electrical resistance[4]
- Measuring current and cathodic protection potential attenuation along the pipeline (attenuation test)[5]
- Inspecting coating quality using direct current voltage gradient (DCVG) method[6]
- Inspecting coating quality of pipelines using close interval potential surveys (CIPS) method[7]
- Inspecting coating quality of buried pipelines using Pearson method[8]
- Inspecting coating quality of pipelines using C-Scan method[9]

In most of the above methods, the interrupter device is an important inspecting element. Manual interrupter: In this type, the cathodic protection current is switched on and off manually. The operators communicate through walkie-talkie. The error of CIPS test for this method is extremely high and it's not used anymore, considering the new technologies [10].

Clocked interrupter: In this type, a clock with a set-time is included. It saves time and prevents the morning return of operators for reinstallation. The error in this type of interrupter is a lot lower than the manual interrupter, but extracting the measured data and their accuracy is highly error-prone, due to unsynchronization with the data logger [11].

Quartz crystals interrupter: This type relies on quartz crystals for correct timing, and it can function as the main unit to be synchronized with similar interrupters. It has a relatively good performance but it doesn't function well enough for tests in which two or more rectifier transformers are placed too far apart because in the CIPS tests, it may be needed to resynchronize all the interrupters for an optimum result [12].

GPS interrupter: It's a more advanced type of interrupters with smaller errors and higher efficiency. This interrupter can be synchronized with data logger perfectly through GPS. Its high price is an obstacle, and in tests where it's needed to synchronize multiple rectifier transformers, it will cost a lot [13], [14].

3. PROCEDURE

In this section, the procedure for improving synchronization of interrupter device in CIPS test using GPS technology is presented. It is as follows:

- Introducing NMEA protocol for connecting to GPS satellites
- Preparing and building a novel interrupter to be synchronized by GPS through introducing L89 IC and how to communicate with it through NMEA protocol
- Installing the interrupter on rectifier transformers of cathodic protection in a real gas pipeline.
- Performing CIPS test using the installed interrupter

3.1. Introducing NMEA Protocol for Connecting to GPS Satellites

Most computer programs that provide real time position information understand and expect data to be in NMEA format. This data includes the complete PVT (position, velocity, time) solution computed by the GPS receiver. The idea of NMEA is to send a line of data called a sentence that is totally self contained and independent from other sentences. There are standard sentences for each device category and there is also the ability to define proprietary sentences for use by the individual company. All of the standard sentences have a two letter prefix that defines the device that uses that sentence type. (For gps receivers the prefix is GP.) which is followed by a three letter sequence that defines the sentence contents. In addition NMEA permits hardware manufactures to define their own proprietary sentences for whatever purpose they see fit. All proprietary sentences begin with the letter P and are followed with 3 letters that identifies the manufacturer controlling that sentence. The hardware interface for GPS units is designed to meet the NMEA requirements. They are also compatible with most computer serial ports using RS232 protocols, however strictly speaking the NMEA standard is not RS232. They recommend conformance to EIA-422. [15], [16]

3.2. The Architecture of Develop System

L86 GNSS module with an embedded patch antenna (18.4mm × 18.4mm × 4mm) and LNA brings high performance of MTK positioning engine to the industrial applications. It is able to achieve the industry's highest level of sensitivity, accuracy and TTFF with the lowest power consumption in a small-footprint lead-free package. The embedded flash memory provides capacity for users to store some useful navigation data and allows for future updates.

L86 module simplifies the device's design and cost because of embedded patch antenna and LNA.

Furthermore, L86 module not only supports automatic antenna switching function, which can achieve Switching between external active antenna and internal patch antenna, but also supports external active antenna detection and short protection. The detection and notification of different external active antenna status will be shown in the NMEA message including external active antenna connection, open circuit for antenna and antenna short-circuited. So host can query the external active antenna status timely and conveniently.

EASY technology as the key feature of L86 module is one kind of AGPS. Collecting and processing all internal aiding information like GPS time, Ephemeris, Last Position etc., the GNSS module will have a fast TTFF in either Hot or Warm start. L86 module is a SMD type module with the compact 18.4mm × 18.4mm × 6.45mm form factor, which can be embedded in your applications through the 12-pin pads with 2.54mm pitch.

If the external active antenna is used, VCC pin will supply power for external active antenna. The typical additional current consumption is about 10mA and 3.3V. It consists of a single chip GNSS IC which includes RF part and Baseband part, a SPDT, a patch antenna, a LNA, a SAW filter, a TCXO, a crystal oscillator, and short protection and antenna detection circuit for active antenna. [17]

After installing the IC and other equipment on the interrupter circuit and programming its microcontroller (MEGA64), the GPS-synchronized interrupter is ready to use. Fig. 1 shows the first GPS-synchronized interrupter built in Iran. It's worth noting that the main microcontroller (MEGA64) of interrupter circuit is programmed using CODE VISION commercial software. The microcontroller is connected to the master computer via a modem. PCS7 of Siemens software is used to connect the interrupter to the master computer.

Fig. 1. The GPS-synchronized interrupter.

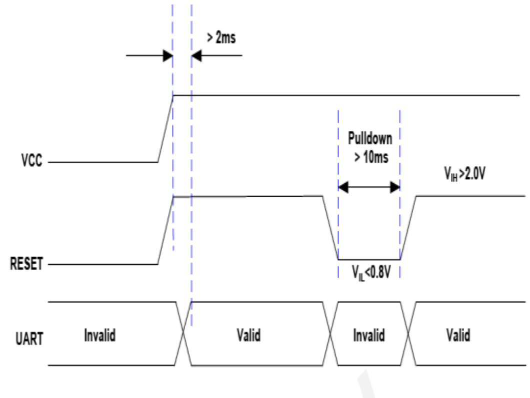

Fig. 2. L86 IC reset schedule [17].

3.3. Installing the Interrupter on Rectifier Transformers

There are different kind of cathodic protection rectifier transformers based on gas pipeline size. The transformer used in our test is a product of Borna Co. The input voltage of the transformer is VAC 220 and the output voltage and current are adjustable between VDC 0-75 and 0-25 A, respectively. The output voltage and current are adjustable depending on the pipeline conditions and coating and cathodic protection test results. The voltage of rectifier transformers are determined by NACE standard as given in Table [18].

Building two novel interrupter and installing them on two rectifier transformers of cathodic protection system was a great step forward in CIPS tests. It allowed us to synchronize transformers on a gas transmission pipeline with a very high efficiency. The pictures below show a rectifier transformer and the interrupter installed on it.

Fig. 3. A rectifier transformer.

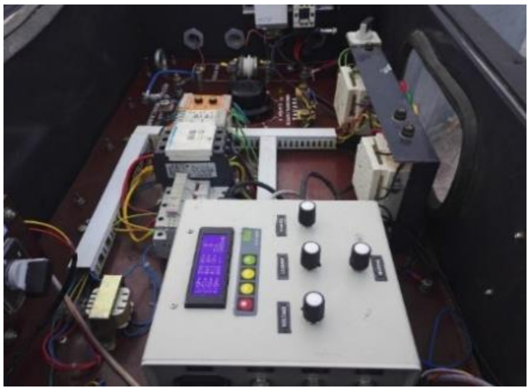

Fig. 4. The interrupter installed on the rectifier transformer.

3.4. Performing the CIPS Test on a 10" Diameter GAS Pipeline

As shown in Fig. 5, the pipeline voltage is measured relative to the soil in 1 km intervals. This method is performed one month after burring the pipe for the first time and then every five years. We used a data logger device made by DCVG Ltd. In England which is one the most advanced and precise equipment in this field and has a memory.

It has many features and is able to transfer the recorded data to Excel through a com port and display them in the form of charts and tables [19].

We adjust the switching on and off time of rectifiers' interrupters so that we can be sure of the off-voltage because higher on-time to off-time ratio will increase the off-voltage. So, it's better to set the ratio as 2:1. Synchronization of interrupters installed on rectifier transformers should be in a way that the on and off error become less than 100 ms. Considering the interrupters used, this criteria is met.

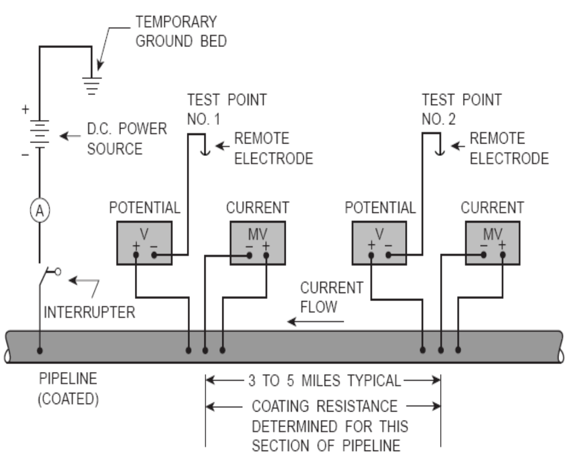

Fig. 5. Schematics of connected devices in the CIPS test [9].

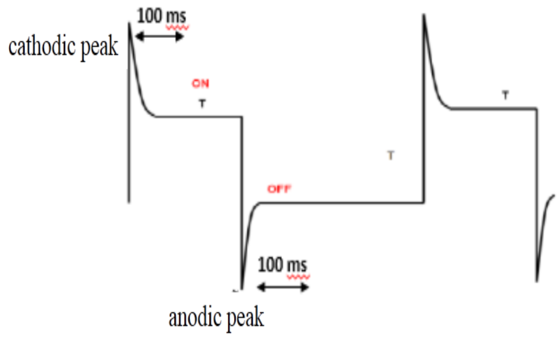

Fig. 6. The waveform illustration of ON and OFF pulses during inspection.

- In this study, the influence of precise synchronization of two rectifier transformers on output variables of CIPS test results in a 48 km long and 10 inch diameter pipeline was investigated using interrupters. Rectifier transformers were installed in 15 and 32 first kilometers of the gas transmission pipeline and the variables are:
- Permanent on-time voltage of TR15 and TR32 transformers without interrupters.
- On-time voltage of TR15 transformer and off-time voltage of TR32 transformer
- On-time voltage of TR32 transformer and off-time voltage of TR15 transformer
- Off-time voltage of TR15 and TR32 transformers

It should be noted that the above variables were recorded frequently and during walking from the start to the end of pipeline. During sampling, it's necessary to record the data at least 100 ms before and after transformer on and off time, due to the error induced by anodic and cathodic peaks.

4. RESULTS

By integrating all the recorded data from the 48 km into the pipeline in respect to aforementioned variables, the figures below are resulted:

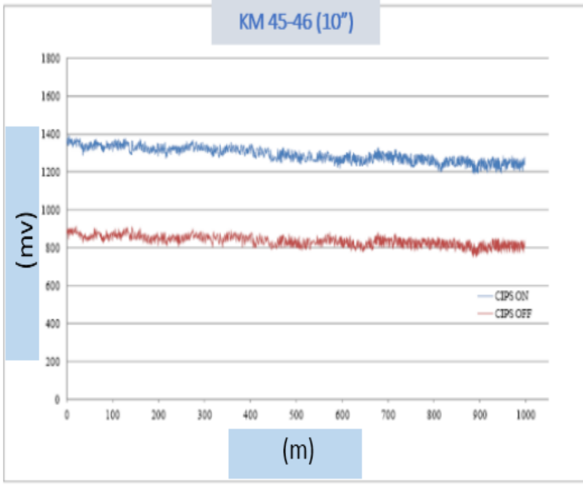

Fig. 7. Sampling with synchronic interruption of TR15 and TR32 transformers 45th Km into the pipeline.

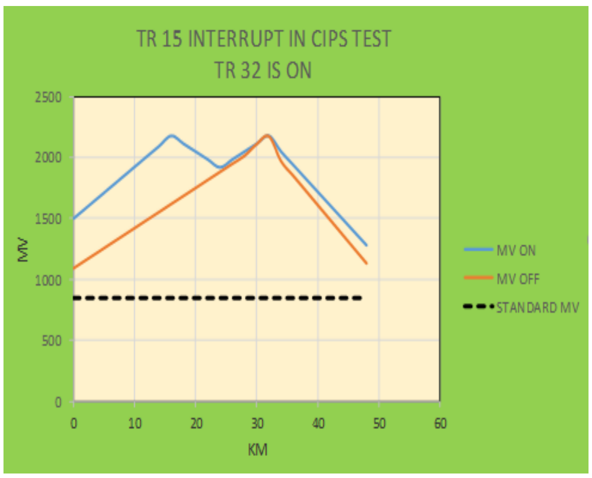

Fig. 8. Sampling during TR32 ON-TIME and TR15 interruption.

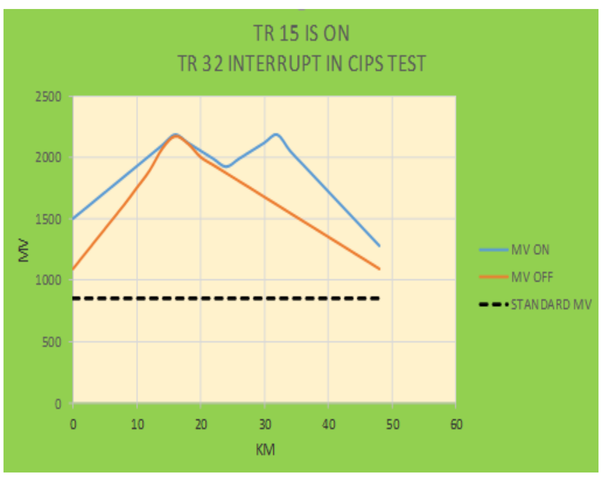

Fig. 9. Sampling during TR15 ON-TIME and TR32 interruption.

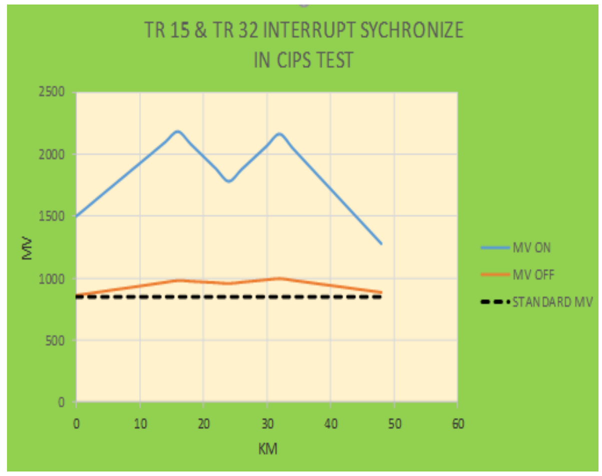

Fig. 10. Sampling with synchronic interruption of TR15 and TR32.

The importance of CIPS test in transmission line inspection, and investigating the results can lead to better understanding about optimization of applied voltage from transformers to the pipeline. On the other hand, excessive voltage can lead to metal hydration under the coating and consequently, increase the corrosion rate in vulnerable points. Accordingly, an improved CIPS test can determine the exact voltage required in various intervals, depending on climate, soil PH and type, and coating type. The most important parameter measured in CIPS tests is the potential difference between pipeline and soil along the pipeline during rectifier transformers on and off times. Since the applied voltage of transformers can affect the off-time potential measurements, switching the transformers on and off in a synchronizing manner can compensate the off-time potential measurement error and leads to more accurate inspection which provide us better cathodic protection level. The transformers are synchronized by the interrupters installed on them. In this study, a novel approach was presented to build and prepare GPS-synchronized interrupters. The results of CIPS tests conducted on a real gas pipeline showed the high effect of interrupter and synchronization on improving the inspection and realization of measured parameters. Furthermore, there is a significant improvement in inspection speed, as well as inspection quality.

5. CONCLUSION

In this study, it was shown that CIPS test can significantly improve cathodic protection process of gas transmission pipelines. Improving CIPS test quality and significant reduction in off-voltage measurement error by building GPS-synchronized interrupters are the prime innovations of this study. Meanwhile, using this kind of interrupters can increase CIPS test speed.

REFERENCES

[1] B.Ahangari, **"Corrosion detection and protection in gas and oil pipelines"**, *Naghoos Press*, 1386.

[2] Research and industrial group parsianfanyaran, **"DCVG-based coating inspection course"**, *NIGC press*, 1389.

[3] M.hashemi, E.khalili, **"operating and maintenance of cathodic protection systems"**, *NIGC press*, 1394.

[4] S. Guan, **"Advanced 100% Solids Rigid Polyurethane Coating Technology for Pipeline Field Joint and Rehabilitation",** *NACE Corrosion Paper*s, 2003, Paper No.03043.

[5] J. Geiser, D. Wessling, **"Local Cathodic Protection for Compressor Stations and Industrial Plants"**, *Germany, Vulkan Publishing Co*, 2001.

[6] A. Aghajani, A. Saatchi, **"Correcting Nonuniform CP Potential Distribution and Interference Problems in a Gas Compressor Station"**, *Material Performance,* 53, Vol. 4, pp. 24-27, 2014.

[7] Y. Du, L. Wang, L. Dong, M. Lu, **"Key Technologies in Regional Cathodic Protection in Oil & Gas Stations"**, *Corrosion, Texas, U.S.A*, 2014.

[8] P. R. Roberge, **"Handbook of Corrosion Engineering"**, *USA, McGraw-Hill*, 1999.

[9] S. papavinasam, chapter11-monitoring-**"external corrosion, corrosion control in the oil and gas industry"**, pp. 715-750, 2014.

[10] Nehad El-Sherif; Michael Nilson; Robert Zweifel , **"Reducing Electrocutions in Industry: Application of a Class C Ground-Fault Current Interrupter in a Pulp and Paper Plant"**, *IEEE Industry Applications Magazine Year*, 2015, Vol. 21, Issue. 1, pp. 49- 53, 2015.

[11] A. J. Kidnay, W. R. Parrish, D. G. McCartney, **"Fundamentals of Natural Gas Processing"**, *Second Edition, CRC Press Taylor & Francis Group,* Boca Raton, FL, USA, pp. 552, 2011.

[12] B. S. Wyatt, **"4.23-cathodic protection instrumentation, shreirs corrosion"**, *management and control of corrosion*, Vol. 4, pp. 2839-2856, 2010.

[13] P. Hopkins, **"Assessing the significance of corrosion in onshore oil and gas pipelines"**, *Underground Pipeline Corrosion*, pp. 62–84, 2014.

[14] Ameer Ameer H. Morad, **"GPS Talking for Blind People"**, *Journal of Emerging Technologies in Web Intelligence*, Vol. 2, No. 3, 2010.

[15] *www.gpsinformation.org/dale/nmea.htm*

[16] Elliott D Kaplan and Christopher Hegarty**, "Understanding GPS: Principles and Applications"**, *Artech House, 2nd ed*., 2006.

[17] GNSS Module Series Rev. L86_Hardware_Design_ V1.0 Date: 2014-09-04, www.cuectel.com.

[18] NACE International the Corrosion Society ©1967, 2001 by NACE International Second Edition 2001.

[19] D Ibrahim, **"Design of a GPS data logger device with street-level map interface",** *Advances in Engineering Software*, Vol. 41, pp. 859-864, 2010.