

Assessment of alternatives for energy efficiency improvement using a hydraulic simulation model

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ABSTRACT

Many water utilities that provide water, drainage and sanitation services in Mexico encounter several problems performing these duties. They face insufficient funds, frequent changes of administrative and qualified technical personnel, as well as distribution-network aging. This situation, along with high water losses in transmission pipelines and distribution networks, illegal service connections, and intermittent water supply have led to a large portion of the water utilities having to deal with a low willingness from the users to pay for the service provided. Pumping and water treatment make up most of the high electricity costs generated from the provision of water supply services.

This paper presents the results of an energy efficiency study, using a hydraulic simulation model as a starting point in which various energy-consumption optimization scenarios were considered. Priority was placed on existing infrastructure use, the assessment of alternatives for pumping equipment operation, the addition of complimentary equipment with its corresponding capital and running costs as well as its repercussions on the service provided to end-users and finally their impact on the total running costs for the water utility. To carry out an adequate interpretation of the hydraulic model, it was necessary to perform a detailed analysis of existing pumping equipment, primarily its electromechanical parameters in such a way that upon integrating them into the model, the proposed alternatives carry the certainty of success.

In general form, the analyzed sources of supply produce an average of 437 L/s, with an energy consumption of 920 kW/h. Based on the hydraulic simulation, it is possible to take 5 pumping sites out of operation from the Pump Stations G.O. 1 and 2 which implies a reduction of 121.7 kW/h and as such, considering the rate at the moment of this study which is \$1.025 kW/h, yields an annual savings of \$55,000.00 USD, representing a 24% decrease in the total energy consumed by the distribution network.

Keywords: Energy saving, Water utilities, Water pumping and treatment

1 INTRODUCTION

Population growth in each of the main cities of the country is shaped by the centralization of public services which places an increasing demand on municipal services like potable water distribution, drainage and treatment. Currently, water demand is met primarily by drawing from deep water wells which requires large amounts of electricity.

With this in mind, operating organisms should aim at increasing and controlling levels of physical and energy efficiency to provide a better service to users as well as to promote efficient and responsible water use while, at the same time, saving energy.

Water use and consumption are significantly linked with the energy required for their supply and treatment. Electricity is estimated to represent around 5-30% of total costs for the operation of water and treatment services (WWAP 2015). According to the IEA (2014) more than 80% of energy in the world is obtained through non-renewable means like carbon, petroleum and natural gas, see Figure 1.

In order to reduce energy consumption without affecting the quantity of water distributed to end-users, it is necessary to define actions that allow for the reduction of physical water losses that take place from the extraction site to its end-points in the communities. These actions must also reduce the energy consumption of the pumping equipment used inside the distribution network.

According to the water balance proposed by the IWA (International Water Association) generally, in potable water distribution systems, the biggest water losses occur because of leaks in the network, tanks and domestic water intakes (Real Losses), observe Figure 2. Water loss in the network can be Real Losses, leaks in the distribution network or tank spillovers and can also be apparent losses that are due to clandestine connections and/or errors in domestic water metering.

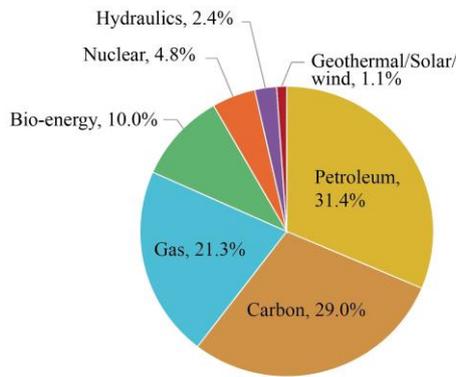


Figure 1. Sources of energy distribution (IEA, 2014).

System input volume	Authorised Consumption	Billed Authorised Consumption	Billed Water Exported	Revenue Water
			Billed Metered Exported	
			Billed Unmetered Exported	
	Water Losses	Unbilled Authorised Consumption	Unbilled metered Consumption	Non Revenue Water
			Unbilled Unmetered Consumption	
		Apparent Losses	Unauthorised Consumption	
			Customer Meter Inaccuracies	
			Leakage on Transmission and Distribution Mains	
Real Losses	Leakage on Overflows at Storage Tanks			
	Leakage on Service Connections up to point of Customer Meter			

Figure 2. Water Balance IWA (Hansen, et al, 2012).

In addition, operating organisms should establish mechanisms to improve their energy performance, such as making wise use of energy and its consumption as well as pursuing energy efficiency. Such mechanisms will help water utilities with their goals of reducing greenhouse gases and other related environmental impacts, as well as decreasing of costs through a systematic energy management, all of this irrespective of the type of energy used (Conagua, 2015).

This article presents the results of applying a methodology to reduce energy consumption and improve energetic efficiency in a potable water distribution network based on a hydraulic-simulation model that adequately describes the initial conditions for the distribution network and permits the evaluation of distinct alternatives to optimize energy consumption.

2 APPLICATION SITE

The methodology presented in this article was implemented in the potable water distribution network of Chetumal City, which is found southeast of the municipality of Othón P. Blanco, in Quintana Roo state, Mexico. The distribution network provides water to 62,040 properties which correspond to a population of 223.344 habitants, largely domestic (IMTA-CAPA, 2016).

The distribution network has two main supply sources, one battery of 12 wells, González Ortega, which contributes an average of 505 L/s and a second battery of wells, Xul-Ha, which contributes another 160 L/s; there are, additionally, four wells distributed within the city, all of which contribute another 131 L/s on average.

The González Ortega well supplies two surface tanks, González Ortega I and II, through which, water is repumped and directed via two pipes, one is 24 inches and the other 20 inches, respectively, to other surface pump stations, UCUM I and II; which, again through repumping, supply a primary tank called TCR via two pipes which are 24 and 20 inches (Figure 3).

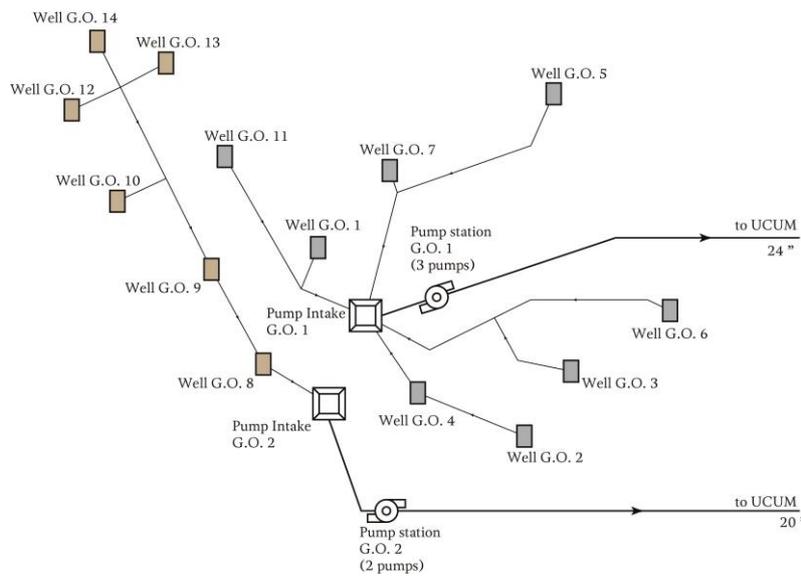


Figure 3. Configuración actual de las captaciones González Ortega

The Xul-Ha wells deliver water to a main tank TCR, through a 14-inch pipe. The TCR feed is also complimented by two other wells and receives a total of 662 L/s.

From the TCR, water flow is pulled by gravity through a 36” steel pipe to different points of delivery as well as to six communities outside of the cities and to properties along the highway (these last properties receive water through a 14” pipe) and to 5 distribution tanks within the city. The delivery points are shown in Figure 4 and Table 1.

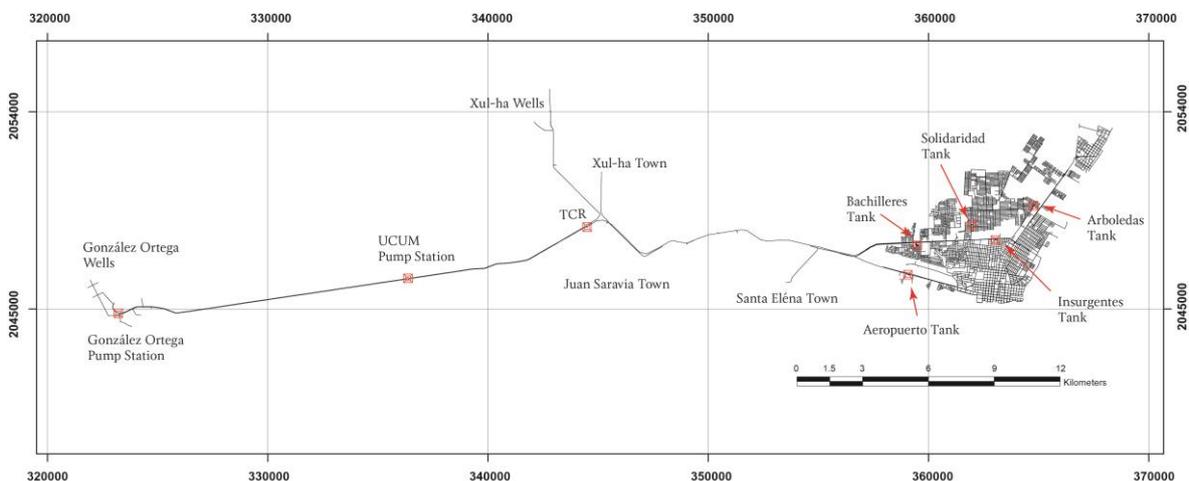


Figure 4. Location of supply sources

Table 1. Derivations to communities and delivery Tanks in the city of Chetumal

Derivation	Consumption	Tank/Sector	Consumption
	L/s		L/s
Pueblo Xul-Ha	12.00	Aeropuerto	95
Pueblo Juan Sarabia	23.82	bachilleres	185
Distrito Escolar	0.65	Solidaridad	85
Zona Industrial	2.99	Insurgentes	135
Pueblo HUAYPIX	23.82	Arboledas	75
Pueblo Santa Elena	33.87		
Derivations along the highway	1.30		

These 5 tanks, or the arrangement of these tanks, define the 5 sectors into which the distribution network is divided within the city.

3 INTEGRATION OF THE NETWORK DISTRIBUTION MODEL

With this information, a hydraulic simulation model was integrated into the Infoworks® WS Plus 16 program, as can be seen in Figure 5, which was then calibrated with direct measurements from the distribution network and with historical data from the operating organism. Once the model accurately represented the network's real operating conditions, it was used to generate proposals to improve energy efficiency in the short, mid and long-term.

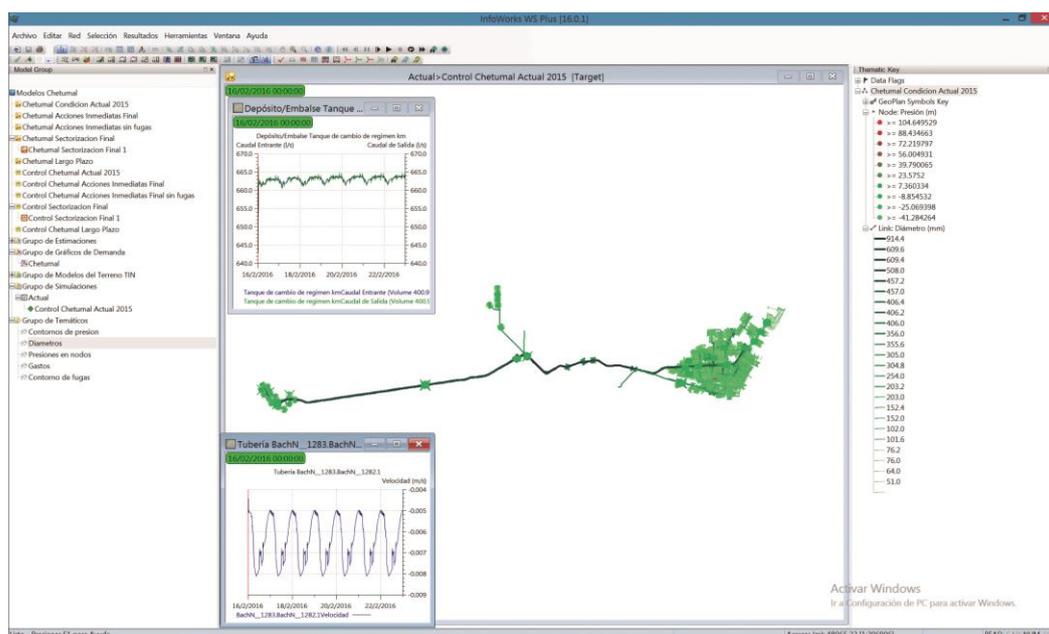


Figure 5. Hydraulic simulation model for the Chetumal city distribution network

Using this model, operating conditions are analyzed to see which could improve or resolve the issue of potable water distribution.

From the general-operation analysis of the distribution network, the problems identified which represent an improvement opportunity in the operation and service given to end-users, can be classified into three types:

- High energy consumption
- Low physical efficiency
- Inadequate distribution of service

Each of these situations will now be described along with the grounds for each and a proposal for a short-term solution.

4 SCENARIO FOR THE REDUCTION OF HIGH ENERGY CONSUMPTION

Inside the distribution network there are 55 pumps which, given the city's topography and proper network arrangement, are assumed to be necessary to guarantee supply to users, nonetheless, the analysis of the piping shows that it is possible to dispense with some of them in the short-term.

A proposal was made to supply the 20" and 24" pipes directly from the wells. For the evaluation, a modification was done to the hydraulic simulation, removing the González I and II pumping stations and placing the discharge arrangements for the delivery of the wells as shown in Figure 6, the arrangement takes advantage of the topography of the site; the abstraction zone is between 15 and 20 meters above the UCUM pump stations.



Figure 6. Piping profile with the location of the Pumps Stations and the TCR

In this way, collection wells are assigned as shown in figure 7 and in Table 2, with the given consumption and flow points, this combination is taken as an optimal efficiency point for the equipment.

Table 2. Assignment of wells to pipes

20" Pipe			24" Pipe		
Well	Water charge	Flow	Well	Water charge	Flow
	m	L/s		m	L/s
G.O. 1	54	39	G.O. 8	27	56.3
G.O. 2	58	30	G.O. 9	27.4	48.43
G.O. 3	45.4	16.3	G.O. 10	30.6	43.3
G.O. 4	48	28.76	G.O. 13	25	35.45
G.O. 5*	86	44.6	G.O. 14	27	36.35
G.O. 6	73	2.6			
G.O. 7	50.25	43.4			
G.O. 11**	40.6	13			
Total		217.66	Total		219.83

* Well currently out of service

** Well reassigned from pipe 2 to pipe 1

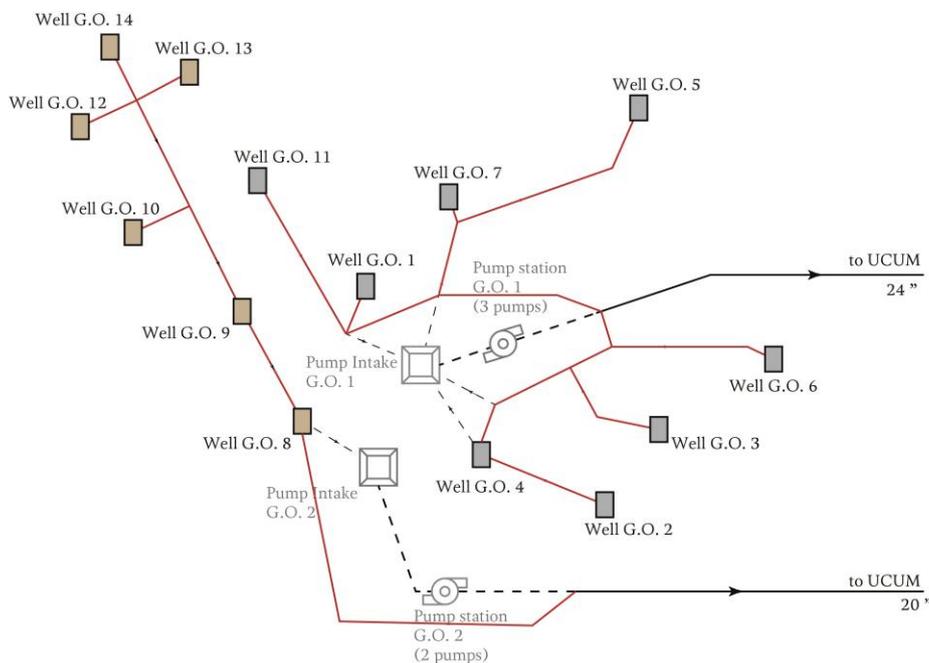


Figure 7. Current reconfiguration of the González Ortega catchments

Based on the hydraulic simulation, it is possible to take 5 pumping sites out of operation from the Pump Stations G.O. 1 and 2 which implies a reduction of 121.7 kW/h (figure 8 and figure 9) and as such, considering the rate at the moment of this study which is \$1.025 kW/h, yields an annual savings of \$55,000.00 USD, representing a 24% decrease in the total energy consumed by the distribution network (figure 10). This situation can be improved upon by increasing physical efficiency to reduce water demand in the supply sources.

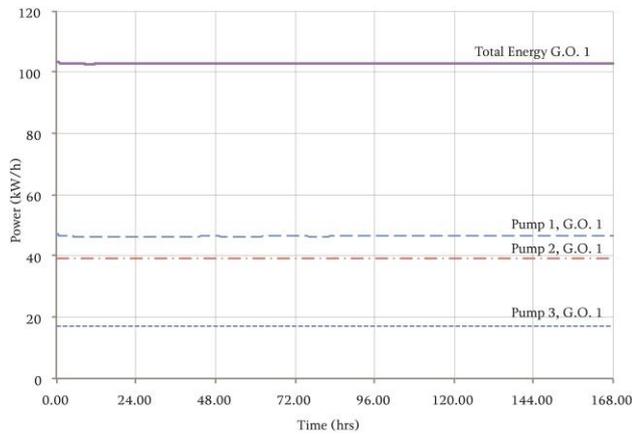


Figure 8. Pump energy consumption at the González Ortega 1 Pump Station

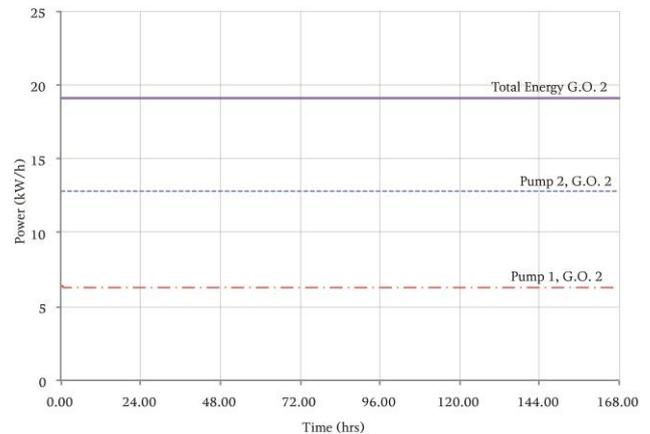


Figure 9. Pump energy consumption at the González Ortega 2 Pump Station

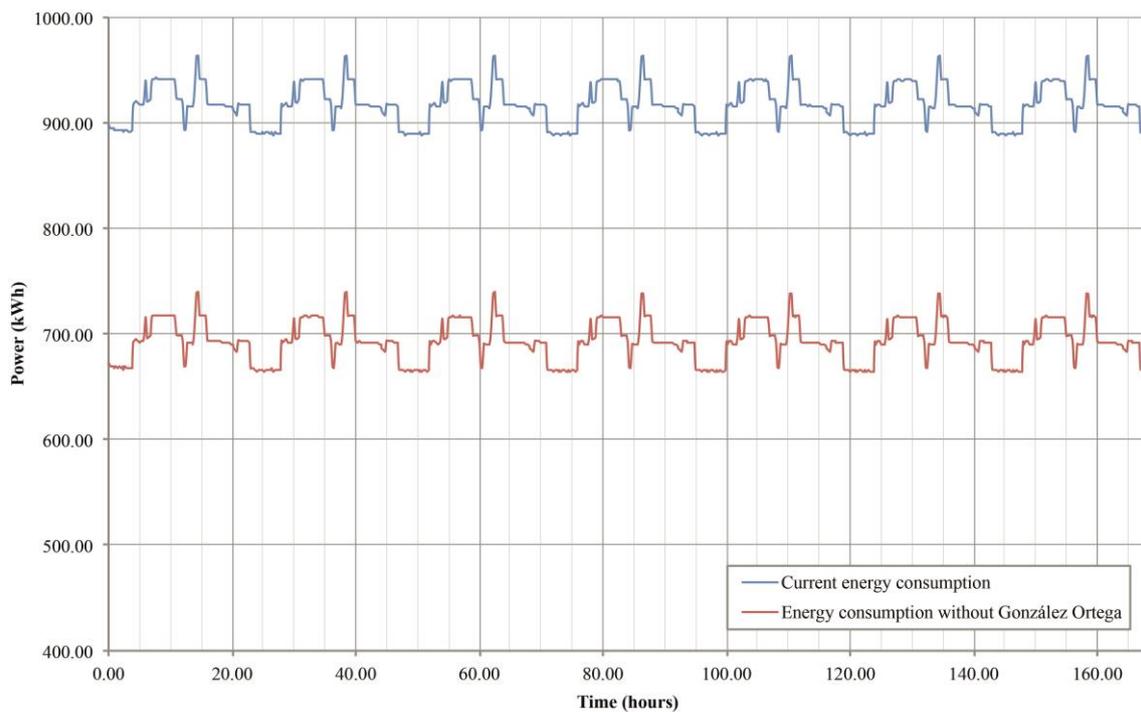


Figure 10. Comparison of current energy consumption without considering the pumping at González Ortega

This proposal is a short-term action that does not consider operational changes beyond the TCR, nonetheless, every action that improves physical efficiency will contribute towards a better performance of water catchments and a decrease in the associated energy consumption.

5 CONCLUSIONS

In conclusion, reducing losses permits the decrease of extraction and at the same time, increases the supply that users receive, nonetheless, as was mentioned previously, to carry out an integral reduction program for water losses, it is recommended to include a network sectorization program.

The result of this work shows the benefits of implementing hydraulic simulation models and taking advantage of their versatility in energy efficiency analysis and operational alternatives evaluation. The precision of the results were possible by measuring the hydraulic and energy parameters directly in the current network and in the installed equipment in keeping with adequate protocols and good engineering practices, which show that the results of the mathematical-simulation model will be as accurate as the data that is gathered from the field. These types of works encourage more energy efficiency projects to be carried out in pursuance of lowering energy consumption in potable water distribution networks, which could represent a decrease in production costs for operating organisms and with it aid their economic self-sufficiency. Having a calibrated hydraulic-simulation model permits the analysis of diverse scenarios, configurations and operation protocols in a relatively short amount of time with minimum investment costs.

References

- [1] WWAP (United Nations World Water Assessment programme), “The United Nations World Water Development Report 2015: Water for a Sustainable World”, *Paris, UNESCO*, 2015
- [2] IEA (International Energy Agency), “World Energy Investment Outlook ”, *Paris, OECD/IEA*, 2014
- [3] P. Hansen, E. Antunez, R. Santos-Tellez, V. Nava, “*Pérdidas Aparentes, Resultados de Censo de Usuarios. Trabajos de campo*”, XXII Congreso Nacional de Hidráulica, Acapulco, México, 2012.
- [4] IMTA (Instituto Mexicano de Tecnología del Agua), CAPA (Comisión De Agua Potable y Alcantarillado de QuintanaRoo), “Estudio Para la Evaluación y Mejoramiento del Sistema de Captación y Conducción de Agua Potable de la Ciudad de Chetumal”, Jiutepec, México, 2016.
- [5] Conagua (Comisión Nacional del Agua), Manual de Agua Potable, Alcantarillado y Saneamiento (MAPAS), “Modelación hidráulica y de calidad del agua en redes de distribución”, México, D.F., Semarnat, disponible en www.mapasconagua.net, 2015
- [6] Conagua (Comisión Nacional del Agua), Manual de Agua Potable, Alcantarillado y Saneamiento (MAPAS), “Eficiencia Energética, Uso Eficiente y Ahorro de la Energía”, México, D.F., Semarnat, disponible en www.mapasconagua.net, 2015
- [7] NOM-006-ENER-2015, Eficiencia energética electromecánica en sistemas de bombeo para pozo profundo en operación.- Límites y método de prueba.
- [8] NOM-029-STPS-2011 “Mantenimiento de las instalaciones eléctricas en los centros de trabajo- Condiciones de seguridad”.
- [9] NMX-J-604-ANCE-2008, "Instalaciones eléctricas-métodos de diagnóstico y reacondicionamiento de instalaciones eléctricas en operación-especificaciones”.