ENVIRONMENTAL RISK ASSESSMENT IN SUBSTATIONS

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ABSTRACT

This work is a survey of environmental risk assessment carried out in compliance with the terms of a technical specification document by CEMIG D, with goals of: Developing indexes of environmental risks associated with potential spillages of insulating oil in substations; Diagnosing each substation of Cemig Distribuição, determining the values of the indexes formulated for environmental risks;
Rating of substation according to the indexes of environmental risks, determining priorities for intervention;
Developing proposals for interventions to control and reduce environmental risk, quantify the costs associated with proposed interventions;
The final product of work includes a descriptive report containing text and tables of data collected and interpreted, stock aerial images of substations and surroundings, with diagrams of water runoff, interactive spreadsheet with data processing and presentation and a proposal for prioritizing actions and cost estimates and implementation schedule.

INTRODUCTION

This study was carried out in compliance with the conditions of the document "Mitigation of Impacts Caused by spillage of insulating oil in Electrical Substations (CEMIG D, May/2009), which established guidelines for evaluating the conditions of Electrical Substations and proposition of mitigation measures in order to reduce or avoid environmental impacts arising from insulating oil spills. The paper presented the basic elements for the development of the Mitigation Plan, as well as the conditions for its development.

The work was accomplished between June 15 and December 10, 2009, and consisted basically of the following steps:

• Action planning through meetings between technical teams of GEOINTEGRA and CEMIG Distribution;
• Development of qualification and quantification models of rates of environmental risks associated with potential spillage of insulating oil;
• Conducting field service covering technical visits to all 364 substations operated by CEMIG D – Figure 1;
• Collecting cabinet information in various databases from CEMIG D, database from public use and other sources;
• Integrated assessment of information and preparation of proposals for interventions aimed at mitigating environmental impacts associated with possible spillage of insulating oil;
• Establishment of prioritization for interventions in terms of environmental risk indexes calculated.

The final product of the work includes, in addition to the descriptive report, a table in a digital format with all the information gathered in field and office, plus a database of aerial images of the substations, in physical and digital formats.

From the field information on the facilities and environmental conditions, a hierarchy of substations was prepared in relation to oil spillage risk, the priority of interventions to reduce or eliminate these risks as well as estimate costs of such interventions.

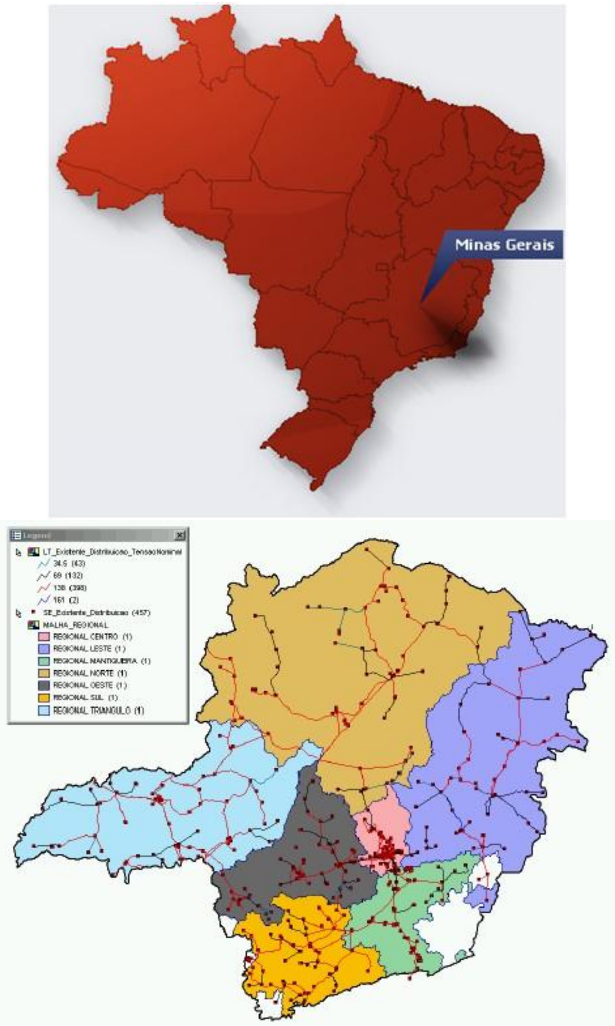

Figure 1. – Location of Minas Gerias state and the substations throughout Cemig's operational grids

METHODOLOGY

In order to deepen knowledge about the potential environmental risk presented by its substations, Cemig Distribuição (Cemig D) and GEOINTEGRA Engenharia Ambiental conducted a survey of all the company's substations, based on methodology for integrated assessment and establishment of indexes for risks of insulating mineral oil spillage, based on the constructive and operational features of the substations, and the environmental variables surrounding the substations.

Information survey

Data was collected on all 364 CEMIG D substations, distributed in seven regional operating grids throughout the company's service area in the state of Minas Gerais - Brazil. To standardize the collection of information, a tabular data collection model was developed in which are related, in summary form, the information inherent to the substations, the purpose of obtaining that information and the way data is showed.

The characteristics of the surroundings of the facilities were also gathered, aiming to assess the sensitivity of the environment, and the consequences and severity of possible spilling of insulating oil in the ambience. After collecting field data, additional office work was conducted in order to:

- Process data gathered through field visits;
- Obtain aerial images of the areas of insertion of the substations;
- Rank surface water bodies surveyed during field visits;
- Calculate distances to Environmental Conservation Lands close to the substations;
- Register records of occurrence of operational accidents in the facilities;

A database of aerial images of the substations and their surroundings was also elaborated, as exemplified on Figure 2.

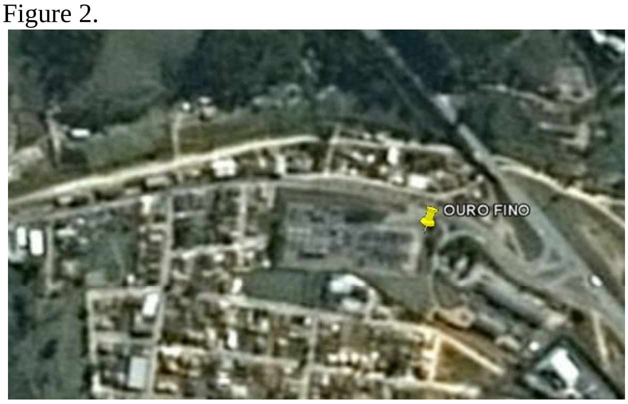

Figure 2. – Aerial image showing a substation (Ouro Fino) and its surroundings

The registration record of accidents was performed with the source accident reports provided by CEMIG and the results of field surveys. The records were released in specific spreadsheet and grouped into two categories: "Accidents with animals" and "other accidents".

Risk Model

The risk assessment model developed for this study predicts that a risk situation is configured when there is simultaneous occurrence of three factors, namely:

- A vulnerable substation (in terms of constructive or operational features) to meteorological conditions or the occupation of its neighborhood and / or the dynamics of change of electrical loads to which the facility is subject;
- Events of operational accident in vulnerable substation with rupture or malfunction in equipment insulated by mineral oil, followed by a considerable amount of oil spillage to the ambience around it.
- The arrival of that volume of oil spilled at different compartments of a critically sensitive environment, causing impacts to environmental quality and / or to the surrounding population and hence the public image of CEMIG D.

To quantify each factor and order the substations according to their relevance to them, indexes were created which descriptions are given below.

Vulnerability of the substation (IVS in Portuguese):

The factors and sub factors interfering in the substation vulnerability are inherent to the surroundings and the region of its insertion. These factors were listed by the project team and each was assessed for its relevance and variability for the formulation of the IVS. For the composition of the IVS, factors and sub factors considering a medium or high relevance were adopted, as shown in Table 1.

Factors of IVS composition				
Factor	**Subfactor**	**Relevance**	**Justification**	**Traceability**
History of accidents	Animals invasion into the substation	High	Historical data are reliable to assess possibility of new events	Accidents counting
Surroundings features	Animals invasion into the substation	Medium	Historical data are numerous and the existence of habitats is easy to distinguish	Identification and counting of habitats
Lightning	Direct strike on equipments	Low	It is a premise that the facility is designed to operate under lightning conditions	Assessing strikes index
Operational overloading	Accidents due to overloading in equipments	Low	It is a premise that the facility is operated under normal load conditions	Counting of preventive maintenance records

Table 1. – Factors for IVS assessing

Potential Operational Risk (IPP in Portuguese)

The formulation of the IPP reflects the severity of a potential accident in operating equipment containing a large volume of oil, and provides a subsidy for the classification of such equipment in relation to its potential for aggression to surrounding communities and environmental compartments in its surroundings, in an accident with oil spillage. Its value is associated with the

constructive features of the equipment and, the greater its value, the greater the potential environmental impact associated with oil spills.
The calculus of the IPP is implemented based on the following factors:

- Amount of oil stored in large equipments;
- Existence of protective devices of large equipment (mainly protection against animal climbing and insulated coverage for connections and bars).
- Existence of containment devices for leaks in large equipment (mainly concrete bunkers);
- Existence and characterization of devices for environmental protection (water-oil separators, collection pits and ponds, etc.).

Table 2 shows part of the facilities ranked according to the Potential Operational Risk

Results for IPP calculation									
Sequence	Facility code	Facility name	Operational Region	V_O	VCR	DEF_D	DEF_{SAO}	PREV	IPP
1	22144	IPATINGA 2	LESTE	27150	1	1	1	1	0,994
2	22144	IPATINGA 2	LESTE	27150	1	1	1	1	0,994
3	22144	IPATINGA 2	LESTE	27150	1	1	1	1	0,994
4	22144	IPATINGA 2	LESTE	27150	1	1	1	1	0,994
5	22144	IPATINGA 2	LESTE	24200	1	1	1	1	0,9918
6	22104	SAO JOAO DEL REI 1	MANTIQUEIRA	23600	1	1	1	1	0,9913
7	22359	CINCO (CONTAGEM)	CENTRO	22800	1	1	1	1	0,9906
8	11101	USINA SALTO GRANDE	LESTE	22655	1	1	1	1	0,9905
9	22344	BH ADELAIDE	CENTRO	22500	1	1	1	1	0,9904
10	22144	IPATINGA 2	LESTE	22000	1	1	1	1	0,99
11	22104	SAO JOAO DEL REI 1	MANTIQUEIRA	21500	1	1	1	1	0,9895
12	22381	PEDRO LEOPOLDO 3	CENTRO	21500	1	1	1	1	0,9895
13	22359	CINCO (CONTAGEM)	CENTRO	21500	1	1	1	1	0,9895
14	22598	BH SAO MARCOS	CENTRO	21000	1	1	1	1	0,9891
15	22598	BH SAO MARCOS	CENTRO	21000	1	1	1	1	0,9891
16	22123	NOVA GRANJA	CENTRO	20500	1	1	1	1	0,9886
17	22244	BOCAIUVA	NORTE	20000	1	1	1	1	0,9882
18	11185	USINA QUEIMADOS	NORTE	18266	1	1	1	1	0,9864
19	22629	UNAI 5	NORTE	18266	1	1	1	1	0,9864
20	22218	CAXAMBU	SUL	18100	1	1	1	1	0,9863

Table 2. – Partial results for IPP

Surroundings sensitivity (ISE in Portuguese)

The ISE was calculated by summing and multiplying accounting of factors associated with the geomorphologic, hydrological and hydro-geological characteristics of the facility region, as well as characteristics of land use in the surroundings. The formula for this calculus was developed as follows:

$\mathbf{ISE} = \mathbf{A_{ISE}} + \mathbf{B_{ISE}} + \mathbf{C_{ISE}} + \mathbf{D_{ISE}} + \mathbf{E_{ISE}}$, where

ISE = Surroundings sensitivity value

$\mathbf{A_{ISE}}$ = Sub factor of sensitivity related to soil features

$\mathbf{B_{ISE}}$ = Sub factor of sensitivity related to underground water

$\mathbf{C_{ISE}}$ = Sub factor of sensitivity related to human activities

$\mathbf{D_{ISE}}$ = Sub factor of sensitivity related to the existence of conservation

$\mathbf{E_{ISE}}$ = Sub factor of sensitivity related to surface water

Proposed Interventions

The completion of the facilities diagnosis and treatment of substation data for the risk assessment enabled the formulation of a draft of interventions, in order to mitigate the environmental impacts of oil spills from equipment at the facilities surveyed. The actions were planned focused on:

- Environmental protection of more sensitive environmental compartments, specially surface water.
- Environmental Conservation Units and surrounding communities of substations.
- Improvement the environmental performance of operations and pro activity related to environmental regulation compliance.
- Operational improvement and reduction of operational risks associated with vulnerability of substations.

Intervention measures

The intervention measures proposed in this paper consist of:

1. Construction of containment basins and oil/water separators, or the interconnection of these devices with existing containment basins, as usually adopted by CEMIG D;
2. Replacement of collecting ponds and tanks by oil/water separators, in order to provide the structures considered ideal for retention of big volumes of oil accidentally spilled by equipments;
3. Installation of devices to prevent accidents with animals in equipment that do not have such devices.

Priority Actions

The proposed priority actions were developed from the grouping of equipment and substations. Thus, the priorities are:

1. Installation of contention basin and oil/water separator and other actions on equipment with large volume of oil (≥ 10,000 l) in substations inserted in sensitive regions, in order of sensitivity of the ambience in which the facility is included.
2. Installation of contention basin and oil/water separator and other actions on equipment with considerable volume of oil (between 1000 and 9999 l) in substations inserted in sensitive regions, in order of sensitivity of the medium in which the facility is included.
3. Replacement of collector ponds and wells for oil/water separator and other actions on equipment with large volume of oil (≥ 10,000 l) in substations inserted in sensitive regions, in order of sensitivity of the medium in which the facility is included. The design of the proposed structures must follow the design currently adopted by

CEMIG D.
4. Replacement of collector ponds and wells for oil/water separator and other actions on equipment with considerable volume of oil (between 1000 and 9999 l) in substations inserted in sensitive regions, in order of sensitivity of the medium in which the facility is included.
5. Installation of structures for animal accident prevention and other actions, in order of sensitivity of the medium in which the facility is included.

RECOMENDATIONS AND APPLICATIONS

The information generated from this survey has brought several gains in quality of maintenance, environmental licensing of facilities and update of existing equipments and components in substations.
As a support tool for maintenance, the scheduling of interventions now relies also on the Index of Surrounding Sensitivity as one of the factors in deciding priority of equipment replacing, together with other data regarding importance of the facility for the system reliability, level of automation and depreciation of operating equipments and substation as a whole.
Another powerful application of the survey results is related to licensing process of our facilities. Brazilian legislation determines that potentially pollutant activities (electricity distribution among them) shall undergo licensing process. For those facilities or activities established before the year of 1981 the process is named Corrective Licensing, and that is the legal requirement most of our substations are obliged to meet. At present the company is carrying out this procedure for about 300 substations, and in most situations we are demanded to present a schedule for the construction of oil/water separation devices, and the schedules we prepare are based on the hierarchy appointed by the survey.
It was also of great help collecting information about almost all equipment insulated by mineral oil in the substations. Despite having a database of equipments, it is not continuously updated and the opportunity to visit each and every facility was used to record that information. It will be also used in planning works of replacement and other maintenance activities.

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