CDM in Sub-Stations by Replacement of SF_6 Gas in Circuit Breaker

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Abstract - This paper gives a case of large Sub-Station Clean Development Mechanism (CDM) Project to analyze CDM project's influence on India's Sustainable Development. SF6 gas is being extensively used in circuit breakers. SF6 gas has the highest Global warming potential which is 23900 times of Carbon Dioxide. Extensive Survey of Sub-Station using SF6 circuit breaker has been done in a sample state of India. Results indicate that there is high leakage of SF6 gas in atmosphere from Circuit Breaker. Quantification of leakage of SF6 gas has been done and CDM project for replacement of SF6 gas from the Sub-Station has been made for sustainable development. Baseline methodology has been proposed for SF6 gas replacement in Circuit Breaker. This paper may become a helpful tool for the policy makers and power system designers.

Keywords – Sub-Station, Circuit Breaker, SF6 gas, CDM, Sustainable Development, Baseline

I. INTRODUCTION

Under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), industrialized countries have assumed binding greenhouse gas (GHG) emissions targets. The 39 states included in Annex I of the Kyoto Protocol have agreed to cut their GHG emissions by an agreed percentage below their 1990 levels in the period between 2008 and 2012 [1]. India is an important player in the carbon credit market, through the implementation of the Clean Development Mechanism. India would be responsible for 6% of the global emissions of gases that cause the greenhouse effect. This paper gives an analysis of CDM projects influence on India's Sustainability in the case of large Sub-Stations. Extensive Survey of Sub-Station using SF6 circuit breaker has been done in a sample state of India namely Haryana. Seventeen sub-stations of 132 KV and above capacity have been surveyed and the amount of leakage of SF6 gas has been quantified. SF6 gas has the highest Global Warming potential which is 23900 times of Carbon Dioxide. Besides this a SF6 circuit breaker has a life of twenty years [2]. At the end of the life of a circuit breaker, on an average 25 kg of gas is released in the atmosphere which is called salvage gas leakage in this case. This salvage gas leakage has been uniformly distributed over the life of the circuit breaker. So on annuity bases salvage gas leakage has been taken as 1.25 kg per year. Besides this annual gas leakage from the circuit breaker has been found by the survey. Large amount of SF6 gas is being released which cause a lot of environmental effects. Therefore, it is one of the strategic options for optimizing for promoting sustainable development in the power System through the Replacement of Circuit Breaker or replacement of SF6 gas with other kind of gas which has lower Green house effect. For the sample survey done in Haryana, Sub-Stations of 132 KV and above capacity has been taken, as lower capacity substations are rarely using this type of circuit breakers.

II. THE CDM – CURRENT STATUS

The scale of these projects is huge. Of the 240 million credits being claimed up to 2012 by 111 projects at the time of writing, 40 million come from two HFC-23 projects and another 70 million from one N2O project; about 46% of all credits from these three projects alone. Two additional HFC-23 projects in India are awaiting successful registration of the first project in Gujarat, while a consortium of Japanese, Italian and Chinese partners are investigating a project spread across 12 HCFC-22 plants in China that would yield 60 million credits a year from 2008 [3]. A February 2004 workshop in China put the total potential of HFC-23 projects at over 100 million credits per year. Carbon market analyst Point Carbon has estimated that projects involving N2O and Perfluorocarbons (PFC) could yield up to 50 million credits a year. And projects that capture methane from coal mines in China are beginning to enter the CDM approvals pipeline with huge carbon credit potential [4]. The vast majority of CDM projects are located in a few, large developing countries. Brazil, India and China account for over 75 per cent of expected annual CERs [5].

III. CDM PROJECT IN SUB-STATION

Although CDM was designed to encourage any types of GHG reduction project development, it has a strict procedure as well as monitoring to accurately measure the reduction of Green House Gas. India has large number of Sub-Stations using SF6 gas, so there will be great potential for the development of such CDM projects by quantifying the SF6 gas that will be released during operation, maintenance, commissioning and salvage of SF6 circuit breakers.

3.1 Operation of Circuit Breaker:

A circuit breaker is a switching device which can open or close a circuit in a small fraction of second. This is achieved due to its separable contacts. The closing and opening of the circuit allows to establish or to interrupt the circulation of current through the circuit under usual or unusual working conditions, such as short circuits.

The interruption process of the current in a circuit breaker, begins when the movable contacts start to separate. As a consequence, the contacts area is reduced and the current density gets larger, until the energy causes the metal to begin vaporizing and an arc appears. In spite of the existence of a physical separation of the switching contacts, the established arc makes possible that the current continues flowing. The interruption of the circulating current will be achieved when the interrupting medium gets to turn the carrying arc plasma into an isolating medium. ([6]-[9])

In SF6 circuit breakers, the current continues flowing after contact separation through arc plasma of ionized SF6. The circuit breaker is designed to direct a constant gas flow to the arc that extracts heat from the arc and so allows achieving its extinction at current zero. The gas flow de-ionizes the contact gap and reestablishes' the required dielectric strength to prevent an arc re-strike [10].

3.2. Assumptions:

Total SF6 losses include leakage in service plus losses during salvage of the circuit breaker. SF6 losses during maintenance are not taken into account. Total SF6 losses are considered to be equivalent to 2% vol. /year as the worst case. They were considered to be equivalent to 0.5% vol. /year as the best case possible [11]. However serving in Indian conditions i.e. extreme hot and extreme cold, its total leakage is taken as 2% and this hypothesis has been tested by our survey report. It is assumed that leakage may be higher which is checked by our survey report.

- It has been assumed that each SF_6 circuit breaker will have 25 kg SF_6 gas and its life will be 20 years. So each circuit breaker on Salvage will release 25 kg gas after 20 years operation. So an annuity bases the salvage leakage of SF_6 has been taken as 1.25 kg per circuit breaker per year.
- SF_6 gas is assumed to be used in sub-stations of 132 kv and above capacity. Cost of 1 CER will be 19 € [23].
- It has been assumed that SF_6 gas will be replaced by the mixture of SF_6/N_2. As an immediate replacement of pure SF_6, the large amount of available physical and laboratory data suggest that a 40% SF_6 - 60% N_2 mixture may exhibit dielectric characteristics suitable for use as insulation in high voltage equipment [12]. N_2 may have overall very less GWP as compare to SF_6. So it's GWP has been neglected or taken as zero.

3.3. Green House Gas Effect:

Climate change is one of the biggest challenges facing the humanity today [13].Greenhouse gases are atmospheric gases which absorb a portion of the infrared radiation emitted by the earth and return it to earth by emitting it back. Potent green house gases have strong infrared absorption in the wavelength range from 7 μm to 13 μm. Sulphur hexafluoride is an efficient absorber of infrared radiation, particularly at wavelengths near

10.5 µm [14]. Because of the many and increasing commercial uses of SF6, there has been an increased demand for it. The estimated world production of SF6 has increased steadily since the 1970s to approximately 7000 metric tons per year in 1993 [15–17, 18, 19]. Additionally, unlike most other naturally occurring greenhouse gases (e. g., CO2, CH4), SF6 is largely immune to chemical and photolytic degradation, therefore its contribution to global warming is expected to be cumulative and virtually permanent [12].

3.4. Process for the CDM project:

The Project owner gives the project idea note and makes the Project Design Document (PDD) for Host Country Approval given by Designated National Authority. CDM Executive Board approves the baseline Methodology and sends the PDD for validation to the operational entity. After validation, registration is done by CDM Executive Board. The Project Owner monitors the emission reduction and verification is done by operational entity. Finally Certified emission reduction (CER) certificates are issued by CDM Executive Board. A project can continue to earn CERs for a maximum of either 10 years (with no change of The baseline) or 7 years with at most two renewals (i.e. up to 21 years) [20].

IV. BASELINE METHODOLOGY

4.1. Project boundary:

Table I: Summary of gases and sources included/excluded in the project boundary

	Source	Gas	Inclu-ded?	Justification / Explanation
Baseline	SF_6 emission from utility equipment (circuit breakers)	SF_6	Yes	The project activity is prevention of SF_6 release into atmosphere.
		CO_2	No	
		CH_4	No	
Project Activity	SF_6 emission from utility equipment (circuit breakers)	SF_6	Yes	The project is prevention of SF_6 release into atmosphere.
		CH_4	No	
		CH_4	No	

The physical boundary is the electrical grid or subset of electrical grid where the project activity of recycling and leak reduction program is implemented. The greenhouse gas included is SF6, which is commonly used as an insulator in electrical transmission and distribution grids. Any part of the Grid where SF6 leak reduction was being implemented prior to the start of project activity shall be excluded from the project boundary

4.2. Procedure for the selection of the most plausible baseline scenario

The methodology covers following categories of SF_6 emissions reductions from the equipments within the project boundary:

- Released SF_6 encapsulated in existing equipment during repairs;
- Released SF_6 encapsulated in existing equipment during decommissioning; and
- Reduction in leaks by repairing the equipments.

The baseline scenario shall be determined by analyzing the following potential alternatives

- Implementing the project activity without CDM; and
- Continuation of the present practice, which shall be described in the CDM-PDD.

Step 1: Assessment of National Policy/regulations on SF_6

- List national or regional policies/regulation that either require reduction of SF_6 emissions from the power sector or prescribe maintenance standards that affects SF_6 release to atmosphere.

- If such policies exist, assess the enforcement of the policies.
- If above-mentioned policies/regulation exists and is enforced, then the project activity implemented without CDM is the baseline scenario.

Step 2: Assess if implementation of SF_6 recycling by any utility or by the utility in any part of its electrical grid is being undertaken.

- Identify and list the level and extent of SF_6 recycling being undertaken with the region where the project activity is implemented.
- If some utilities do under taken SF_6 recycling, are there factors that prevent the implementation of the same activity within the project boundary of the project activity. If not then the project activity implemented without CDM is the baseline scenario. Documented evidence for factors preventing implementation shall be reported in the CDM-PDD and validated by the DOE [21].

This methodology is applicable only if the baseline scenario is continuation of the present practice.

4.3. Additionality:

Additionality shall be demonstrated using the latest version of the "Tool for the demonstration and assessment of additionality". In addition, it must be shown that no sectoral or regional/national-level policies exist that require the recycling or leak management of SF_6 in electric utility infrastructure.
The barriers listed below should be evaluated as part of the application of the latest version of the "tool for the demonstration and assessment of additionality":

1. Investment barriers, other than the economic/financial barriers:

- Real and/or perceived risks associated with the technology or process is too high to attract investment;
- Funding is not available for innovative projects.

2. Technological barriers:

- Skilled and/or properly trained labour to operate and maintain the technology is not available, leading to equipment disrepair and malfunctioning.

3. Barriers due to prevailing practice:

- Developers lack familiarity with state-of-the-art technologies and are reluctant to use them;
- The project is the "first of a kind".
- Management lacks experience using state-of-the-art technologies, so that the project receives low priority by management.
- Perceived technical and financial risks to enterprises (fears that a new technology may not work, could interrupt production, take time to perfect, or will not actually result in financial savings).
- Real and perceived insignificance of many investments – for example, if energy efficiency (or SF_6) projects are relatively small and the value of the savings achieved typically is only a small percentage of enterprise operating costs.

These identified barriers are to be considered only if they would prevent potential project proponents from carrying out the proposed project activity were it not registered as a CDM activity.

V. MATERIAL AND METHODS

Thorough analyses of the Survey of sub-stations, SF_6 gas emission from circuit breaker is known for Haryana state.
The Survey list of the Sub-Station in this paper is arranged in Table 2.

Table 2: Survey List Substation

Sub-Station	Size	No. of C.B	Gas Filled in a C.B kg/year	Gas Filled in Sub-Station kg/year
BadshaPur	220 KV	21	2-2.5	20

Narnaul	220 KV	11	3-4	7
Ch. Dadri	132 KV	10	1	2.5
Karnal	132 KV	4	2-3	4
Karnal	220 KV	16	4-5	7
Mohindergarh	220 KV	18	2-3	8
Palla	220 KV	12	2-3	9
Rewari	220 KV	14	4	12
Nising	220 KV	23	4	12
Murthal	132 KV	5	2	5
Kurukshtra	220 KV	10	2	7
Sect-56,Gurgoan	220 KV	15	0	0
Sect-52,Gurgoan	220 KV	19	0	0
Daulta Baad	220 KV	22	4	12
IMT,Manesar	220 KV	10	0	0
Sonepat	220 KV	10	5	8
BBMB Dadri	220 KV	14	0	0
Total no. of circuit breaker=234			Average of gas filled per circuit breaker per year=0.489 kg	
Average of SF6 gas filled per sub-station per year=			6.676 kg	

VI. CALCULATION

5.1. For Complete One Sub-Station

I. Step 1: Baseline emissions

$$BE_y = (TG_x + SV_x) \times \frac{GWP_{SF6}}{1000}$$

Where:

BE_y = Baseline emissions during the year *y* (tCO_2/yr)

TG_x = Total gas (SF_6) emitted from one sub-station (kg SF_6)

SV_x = Salvage Value of each sub-station (kg SF_6)

GWP_{SF6} = Global warming potential of SF_6 (tCO_2e/tSF_6)

$$= (6.676 + 1.25) \times \frac{23900}{1000}$$

BE_y = 189.44 tCO_2/yr

Step 2: Project Emissions

As we replaced pure SF_6 with mixer of gas having composition 40% SF_6 and 60% N_2

$$PE_y = [40\ \%\ \text{of leaked}\ SF_6\ \text{gas i.e.}\ (TG_x + SV_x)] \times \frac{GWP_{SF6} +}{1000}$$

$$[60\ \%\ \text{of leaked}\ N_2\ \text{gas i.e.}\ (TG_x + SV_x)] \times \frac{GWP_{N2}}{1000}$$

$$= (3.17) \times \frac{23900}{1000} + (4.75) \times \frac{0000}{1000}$$

PE_y = 75.76 tCO_2/yr

Where:

PE_y = Project emissions during the year *y* (tCO_2/yr)

GWP_{SF6} = Global warming potential of SF_6 (tCO_2e/tSF_6)

GWP_{N2} = Global warming potential of N_2 (tCO_2e/tSF_6)

Step 3: Emission reductions
Emission reductions are calculated as follows:

$ER_y = BE_y - PE_y$

Where:
ER_y = Emission reductions during the year *y* (tCO_2/yr)
BE_y = Baseline emissions during the year *y* (tCO_2/yr)
PE_y = Project emissions during the year *y* (tCO_2/yr)

$= 189.44 - 75.76$

$ER_y = 113.68\ tCO_2/yr$

Step 4: Calculation of the cost of emission reduction

$ER_y = 113.68\ tCO_2/yr$

CER will be equal to tones of CO_2 released in a year [22]
So in this case CER will be =113.68

Cost of 1 CER will be 19 € [23].
So total earning from CER=19 x 113.68

= € 2159.92 per year per Sub- Station

5.2. For One Circuit-Breaker

II. Step 1: Baseline emissions

$$BEy = (TGx + SVx) \times \frac{GWPSF6}{1000}$$

Where:
BEy = Baseline emissions during the year y (tCO2/yr)
TGx = Total SF6 emitted from one sub-station (kg SF6)
SVx = Salvage Value of each sub-station (kg SF6)

$$= (0.485 + 1.25) \times \frac{23900}{1000}$$

= 41.46 tCO2/yr.

Step 2: Project Emissions

As we replaced pure SF6 with mixer of gas having composition 40% SF6 and 60% N2

$$PEy = [40\ \%\text{ of leaked SF6 gas i.e. } (TGx + SVx)] \times \frac{GWPSF6}{1000} + [60\ \%\text{ of leaked N2 gas i.e. } (TGx + SVx)] \times \frac{GWPN2}{1000}$$

$$= (0.694) \times \frac{23900}{1000} + (1.04) \times \frac{0000}{1000}$$

= 16.58 tCO2/yr.

Where:
PEy = Project emissions during the year y (tCO2/yr)
GWPSF6 = Global warming potential of SF6 (tCO2e/tSF6)
GWPN2 = Global warming potential of N2 (tCO2e/tSF6)

Step 3: Emission reductions

Emission reductions are calculated as follows:

ERy = BEy − PEy

Where:
ERy = Emission reductions during the year y (tCO2/yr)
BEy = Baseline emissions during the year y (tCO2/yr)
PEy = Project emissions during the year y (tCO2/yr)

= 41.46 - 16.58

= 24.88 tCO2/yr

Step 4: Calculation of the cost of emission reduction

ERy = 24.88 tCO2/yr

CER will be equal to tones of CO2 released in a year [22]
So in this case CER will be =24.88

Cost of 1 CER will be 19 € [23].
So total earning from CER=19 x 24.88

= € 472.72 per year per circuit breaker

VII. RECOMMENDATION

Sulfur hexafluoride is a superior dielectric gas for nearly all high voltage applications. It is easy to use, exhibits exceptional insulation and arc-interruption properties, and has proven its performance by many years of use and investigation. It is clearly superior in performance to the air and oil insulated equipment which was used prior to the development of SF_6-insulated equipment. However, the extremely high global warming potential of SF_6 mandates that users actively pursue means to minimize releases into the environment, one of which is the use of other gases or gas mixtures in place of SF_6.

An evaluation of the results of the last two decades, and a detailed analysis of the data presented in this report, indicate that no replacement gas is immediately available for use as an SF_6-substitute (“drop-in gas”) in existing electric utility equipment. For gas insulated transmission lines and gas insulated transformers, the limitation is primarily due to the need for re-certification and possible re-rating of equipment that is already in use. For gas insulated circuit breakers there are still significant questions concerning the performance of gases other than pure SF_6.

However, various gas mixtures show considerable promise for use in new equipment, particularly if the equipment is designed specifically for use with a gas mixture:

- Mixtures of nearly equal amounts of SF_6 and N_2 exhibit dielectric properties that suggest that they could be used as a “universal application” gas for both electrical insulation and arc/current interruption purposes. In this connection, standard procedures for mixture handling, use, and recovery would need to be further developed.
- Mixtures of low concentrations (<15%) of SF_6 in N_2 show excellent potential for use in gas insulated transmission lines, although further work on their performance in practical systems is necessary.
- Pure high pressure nitrogen may be suitable for some electrical insulation applications. Consideration of the use of such environmentally friendly gases where SF_6 is not absolutely required should be investigated and promoted.
- A mixture of SF_6 and helium has shown promise when used in gas insulated circuit breakers, and should be investigated further. Finally, it is clear that a significant amount of research must be performed for any new gas or gas mixture to be used in electrical equipment. Such a program necessarily would require the systematic study of potential replacements, including their physical, chemical, and performance properties. A concerted effort in this area by equipment manufacturers, utilities, government labs, universities, and gas manufacturing companies would be beneficial [12].

VIII. CONCLUSIONS

- Since our hypothesis is 2% i.e. 0.5 kg/year leakage of SF_6 gas and by survey reported this hypothesis is tested and it has been found to 1.94% i.e.0.485 kg/year.
- The replacement of SF_6 gas by SF_6/N_2 40%/60% composition results in lesser GWP of the leaked gases.
- Average of SF_6 gas filled per circuit breaker per year is found to be 0.489 kg by the survey report.
- Number of carbon credits earned will be 113.68 CER per sub-station per year.
- If this project of SF6 gas replacement by SF6/N2 mixture is approved as CDM project then earnind per sub-station per year will be € 2159.92

Technology Status/Application

Electric power systems: At least one utility is known to use SF_6/N_2 and SF_6/CF_4 gas mixtures for circuit breakers used in cold weather, at transmission and sub-transmission voltage levels (i.e., 500 kV and below) [24].

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