Life Cycle Assessment on a 765 kV Venezuelan Transmission System

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Abstract

The demand to preserve the environment and form a sustainable development is greatly increasing in the recent decades all over the world, and this environmental concern is also merged in electrical power industry, resulting in many eco-design approaches in T&D industries.

As a method of eco-design, Life Cycle Assessment (LCA) is a systematic tool that enables the assessment of the environmental impacts of a product or service throughout its entire life cycle, i.e. raw material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product's existence.

In T&D industries, LCA has been done for a lot of products individually, in order to see one product's environmental impacts and to seek for ways of improving its environmental performance. This eco-design for product approach is a rather well-developed trend, however, as only a single electrical product cannot provide the electrical power to users, electrical system consists of a huge number of components, in order to investigate system's environmental profile, the entire environmental profiles of different composing products has to be integrated systematically, that is to say, a system approach is needed.

Under this philosophy, in this paper, an LCA using SimaPro (one kind of LCA software) is conducted on a whole Venezuelan 765 kV AC transmission system, which transmits 8000 MW hydro-electrical power through 760 km to this country's load centers, with total 7 substations, i.e. one sending end, 2 intermediate substations and 4 receiving ends. This LCA includes both transmission lines and substations, and then the environmental impacts of the whole transmission system are investigated.

Key Words:

Eco-design; LCA; Transmission System; 765 kV AC;

1. Introduction

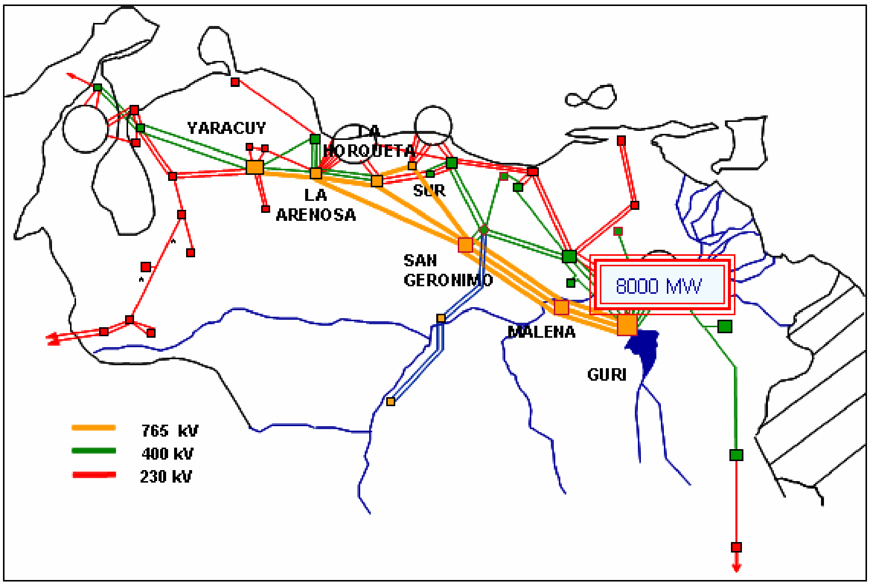

Fig. 1 : Illustration of Venezuelan 765 kV AC transmission system

Fig. 1 shows this Venezuelan 765 kV AC transmission lines, which transmits 8000 MW hydro-electrical power from Guri to this country’s load centers, located in the north of the country. 4 receiving end substations are Yaracuy, La Arenosa, La Horqueta and Sur, and the distance from Guri to the receiving end is around 760 km. 2 intermediate substations, i.e. Malena and San Geronimo are built to make reactive compensation. Then in this paper, an LCA is to be performed on this 765 kV AC transmission system.

2. LCA

LCA is a systematic tool that enables the analysis of the environmental impacts of a product or service throughout its entire life cycle, as well as the potential impacts on the environment[1]. The term 'life cycle' refers to raw material production, manufacture, distribution, use and disposal including all intervening transportation steps necessary or caused by the product's existence, see Fig.2. The assessed environmental impact indicators contain: Global Warming (GWP), Air Acidification (AA), Ozone Depletion (ODP), Photochemical Ozone Creation (POC), Water Eutrophication (WE), Air Toxicity (AT), Water Toxicity (WT), Raw Material Depletion (RMD), Energy Depletion (ED), Hazardous Waste Production (HWP), Water Depletion (WD), etc.

On making LCA, software SimaPro is used, which is a professional tool to collect, analyze and follow the environmental performance of products and services using several inventory databases with thousands of processes and the most important impact assessment methods. It is a software package that allows modelling and analyzing complex life cycles in a systematic and transparent way, following the ISO 14040 series recommendations[2].

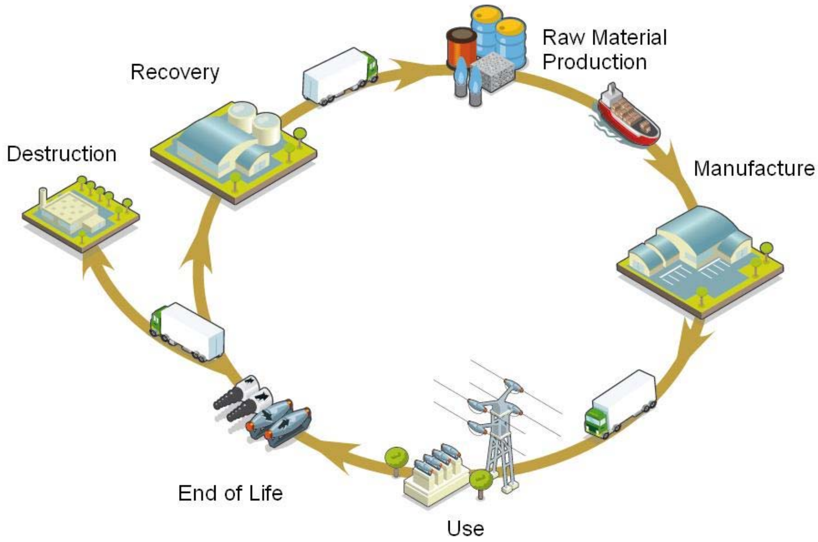

Fig.2 : Life Cycle Notion[3]

An LCA is conducted to investigate environmental profile of this 765 kV AC transmission project, and this LCA is split up into 2 parts, i.e. LCA of Over-Head Line (OHL) and LCA of substations.

3. LCA of Over-Head Lines

In this study, OHL concludes conductors, ground wires, towers and insulators. Raw materials of different components of OHL, use phase of OHL (ohmic losses) and End of Life is taken into account in the LCA.

Table 1 shows different materials used in OHL, foundations are also taken into account.

Table 1 : Materials used in 765 kV AC transmission line

components	material	weight
conductors	Al	48 900 ton
ground wires	Al	182.9 ton
	steel	1593.8 ton
towers	steel	86 475 ton
	reinforced concrete	186 466 ton
	Zn coatings	4217.4 ton
insulators	ceramic	2811.6 ton
	cast iron (cap + pin)	4185.2 ton

As for the ohmic losses of OHL, 3 circuits are used to transmit 8000 MW power from Guri to load centers, so each circuit transmit 2667 MW power. Power factor is assumed to be 0.98, then according to Eq. 1, and Eq. 2, the current in each phase is

2.05 kA. As the length of single circuit is 2280 km, the resistance of conductor is 0.01204 (Ω/km @25^{o}C), and according to Eq. 3, total ohmic losses of all the OHL is 346 MW, excluding the substations' losses, which means a power loss of 4.3%. Under full capacity, and in its service life of 60 years of this UHVAC line, electrical energy losses: 1.82 × 10^8 MWh.

$$S \cos\varphi = P \qquad \text{(Eq. 1)}$$

in which :

S – apparent power

cosφ – power factor of transmission line

P – active power

$$S = \sqrt{3}UI \qquad \text{(Eq. 2)}$$

in which :

S – apparent power

U – line-to-line voltage

I – line current

$$Loss_{joules} = 3I^2R \qquad \text{(Eq. 3)}$$

in which :

$Loss_{joules}$ – ohmic losses

I – line current

R – line resistance

LCA results

A life cycle analysis is conducted by using software SimaPro 7.1, method EDIP/UMIP 97 version 2.03. Materials used in transmission line, utility (ohmic losses in 60 years), and end-of-life of these materials (except concrete) are taken into account in the LCA.

Fig. 3 indicates the characterization results of LCA, for each environmental indicator it shows the comparison of degree of environmental impacts among materials (lines), utility (Electricity UCPTE Hydro I) and end-of-life (EoL of entire lines). For many environmental indicators, the end-of-life appears the negative environmental impacts, which means end-of-life can avoid a certain amount of environmental loads, because it avoids exploiting more raw materials, consequently, its beneficial to the environment.

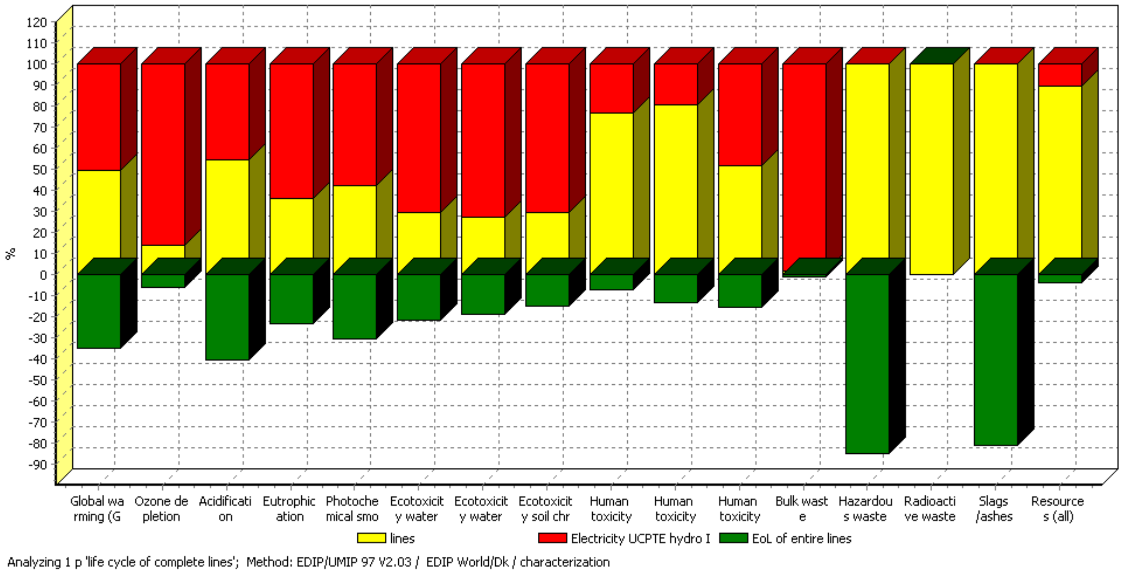

Fig. 3 : characterization result of LCA of Venezuelan 765 kV AC transmission line by SimaPro

The environmental impacts of Venezuelan 765 kV AC OHL lines are shown in Table 2.

Table 2 : characterization result of LCA of 765 kV AC transmission line

Impact category	Unit	Total	lines	Ohmic loss	EoL of entire lines
Global warming (GWP 100)	g CO2	9,97E+11	7,53E+11	7,79E+11	-5,35E+11
Ozone depletion	g CFC11	1,59E+05	2,35E+04	1,45E+05	-9,87E+03
Acidification	g SO2	5,18E+09	4,74E+09	4,01E+09	-3,57E+09
Eutrophication	g NO3	4,80E+09	2,26E+09	4,02E+09	-1,48E+09
Photochemical smog	g ethene	3,74E+08	2,28E+08	3,13E+08	-1,67E+08
Ecotoxicity water chronic	m3	3,19E+11	1,19E+11	2,86E+11	-8,68E+10
Ecotoxicity water acute	m3	3,21E+10	1,07E+10	2,89E+10	-7,56E+09
Ecotoxicity soil chronic	m3	1,13E+10	3,91E+09	9,31E+09	-1,95E+09
Human toxicity air	m3	5,32E+14	4,39E+14	1,34E+14	-4,11E+13
Human toxicity water	m3	1,74E+10	1,62E+10	3,91E+09	-2,68E+09
Human toxicity soil	m3	5,22E+07	3,20E+07	2,98E+07	-9,60E+06
Bulk waste	kg	3,83E+09	6,68E+07	3,80E+09	-3,98E+07
Hazardous waste	kg	1,54E+04	1,04E+05	0,00E+00	-8,91E+04
Radioactive waste	kg	6,25E+02	6,25E+02	0,00E+00	2,70E-01
Slags/ashes	kg	9,75E+06	5,21E+07	0,00E+00	-4,23E+07
Resources (all)	kg	2,94E+05	2,74E+05	3,14E+04	-1,12E+04

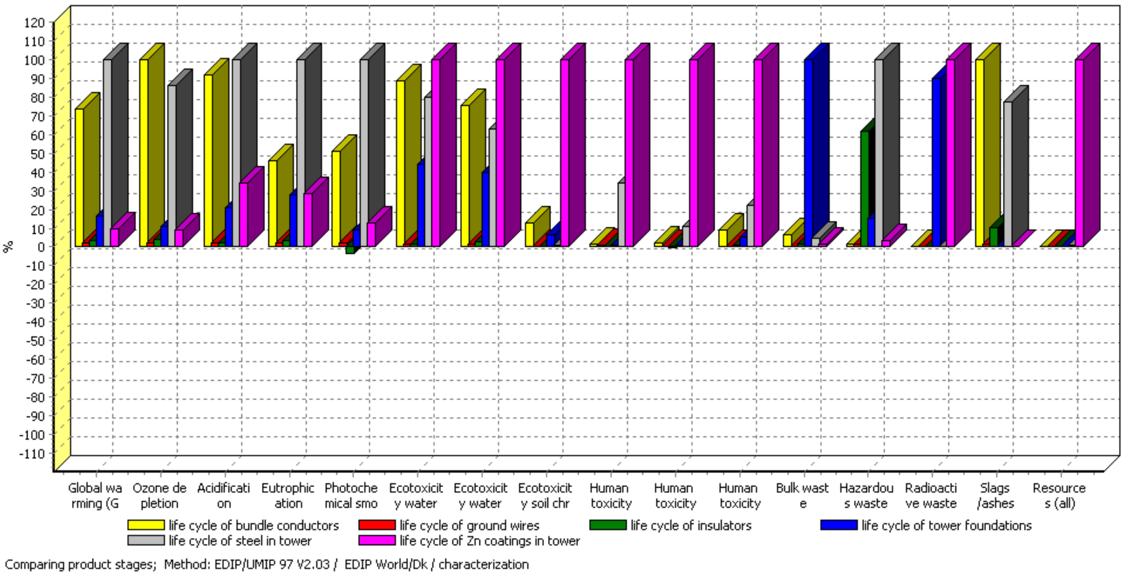

Fig. 4 : Characterization results for comparisons of environmental impacts
for different OHL components

Fig. 4 shows comparisons of environmental impacts between different parts of OHL, it’s notices that :

1) Towers show major impacts in most categories, as towers consume more raw material (steel) compared to the rest components, and contain Zn coatings.
2) Although steel in towers is recycled, due to the fact that, in some impact categories, the steel recycling process itself make more impacts than it potentially reduces by useful recycled steel.
3) Zn coatings show huge impacts in eco-toxicity, human toxicity, etc.
4) Insulators have less environmental impacts as they consume comparatively less materials.

4. LCA of Substations

Through the same LCA approaches shown for OHL, an LCA is also conducted on 7 substations, i.e. all the major primary equipments including power transformer, circuit breaker, current transformer, voltage transformer, disconnector, post insulator, surge arrester, coupling capacitor, line trap, etc.

Due to confidential reasons, the LCA results will be given during the meeting.

5. Conclusions & Discussions

The LCA indicate precisely environmental impacts of this Venezuelan 765 kV AC transmission system, which makes possible to compare environmental performances with the integration of state-of-art technologies, such as HVDC, FACTS, and replacement or refurbishment of components, this makes it possible to develop methodologies of reducing this transmission system's environmental impacts.

6. References

[1] ECODESIGN: Best Practice of ISO/TR 14062, Committee on Trade and Investment February 2005. Page 16

[2] SimaPro 7.0. PRé Consultants 2006,Netherlands.

[3] Wenlu WANG, Naihu LI, Abderrahmane BEROUAL, et al. Implementation of an Eco-design Methodology within AREVA T&D. CIGRE International Symposium on Operation and Development of Power Systems in the New Context, Guilin City, Guangxi Province, China, Oct 28-30, 2009.