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The Los Azufres III (75MW) Expansion Project in the Los Azufres Geothermal Field, México

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ABSTRACT

In 1982 commercial exploitation of The Los Azufres geothermal field, Mexico, began with the installation and commissioning of the first 5 backpressure turbine generator units, 5 MW each, and was increased until reaching an installed capacity of 188 MW with the addition of 4 units of 25 MW each in 2003. The field contains fourteen units distributed as follows: 5 in the southern part fed by the steam of 18 producing wells, 2 units of binary cycle using residual brine and 7 units in the northern fed by the steam of 22 wells. Of these, seven are backpressure of 5 MW capacity each, and with specific consumption averaging 13.7 t/h-MW. Three are located in the south and four in the north.

This paper presents the Los Azufres Project III (75MW), which aims to achieve greater efficiency in the utilization of geothermal resources for power generation. This allows the replacement of 7 backpressure units, with a high specific consumption and close to fulfilling their lifetime, for two to condensation, of lower specific consumption, one of 50 MW, located in the north and another 25 MW in the south. This reduces the fuel economy of 13.7 to 7.2 t / h-MW (47.4%). Without the withdrawal of 7 units, the installed capacity would have increased from 188 MW to 228 MW, without drilling new wells.

Based on the foregoing, it is proposed to develop a geothermal project of 75 MW, sustainably and in harmony with the requirements of energy for economic and social development in the region by 2012, replacing backpressure plants by other more efficient condensation plants. It defines the basic criteria for drawing up the feasibility study, basic engineering Los Azufres III Project and the Environmental Impact Statement.

1. Introduction

The Los Azufres geothermal field is located in the Sierra de San Andres, on the edge of the eastern state of Michoacan, 80 km East of the city of Morelia and 250 km from Mexico City (Figure). It has two access roads, built and preserved by the CFE: one north, linked with Federal Highway No.12-Morelia Mexico, and the second, south, linked with Federal Highway No.15-Morelia Ciudad Hidalgo (Figure 1). It is a volcanic complex located at an average elevation of 2800 meters above sea level. The area is forested, considered since 1979 as a Forest Protection Zone. The sector studied comprises an area of 56 km^2.

In 1982 commercial exploitation of the field began with the installation and commissioning of the first five backpressure turbine generator units, 5 MW each, and was increased gradually until 2003, when 4 condensing units of 25 MW each were put

Figure 1. Location of the Los Azufres Geothermal Field.

Table 1. Dates of entry into operation of all units in Los Azufres.

Unit	Brand	Power MW	Date of Entry into Operation
U-2	Mitsubishi	5	4-Ago-1982
U-3	Mitsubishi	5	10-Ago-1982
U-4	Mitsubishi	5	17-Ago-1982
U-5	Mitsubishi	5	26-Ago-1982
U-6	Toshiba	5	23-Dic-1986
U-7	General Electric	50	12-Nov-1988
U-9	Ansaldo	5	24-Abr-1990
U-10	Ansaldo	5	14-Oct-1992
U-11	Ormat	1.5	03-Jul-1993
U-12	Ortmat	1.5	7-Oct-1993
U-13	Alstom	25	30-Ene-2003
U-14	Alstom	25	7-Feb-2003
U-15	Alstom	25	10-May-2003
U-16	Alstom	25	2-Jul-2003

into service. Table 1 shows the dates of entry into operation of all units.

Currently the installed capacity is 188 MW, consisting of fourteen units distributed as follows: five in the south fed by the steam of a group of 18 producing wells, two units of binary cycle using residual brine and seven units in the northern fed by the steam of 22 wells. To keep operating units producing 14 million tons of endogenous steam annually, on average, and 6.9 million tons of brine that is injected into the reservoir through 6 injectors wells, in order to recharge the same and avoid further negative impacts on the environment (Figure 2).

Aiming to establish the sustainability of the Los Azufres project and use the steam more efficiently

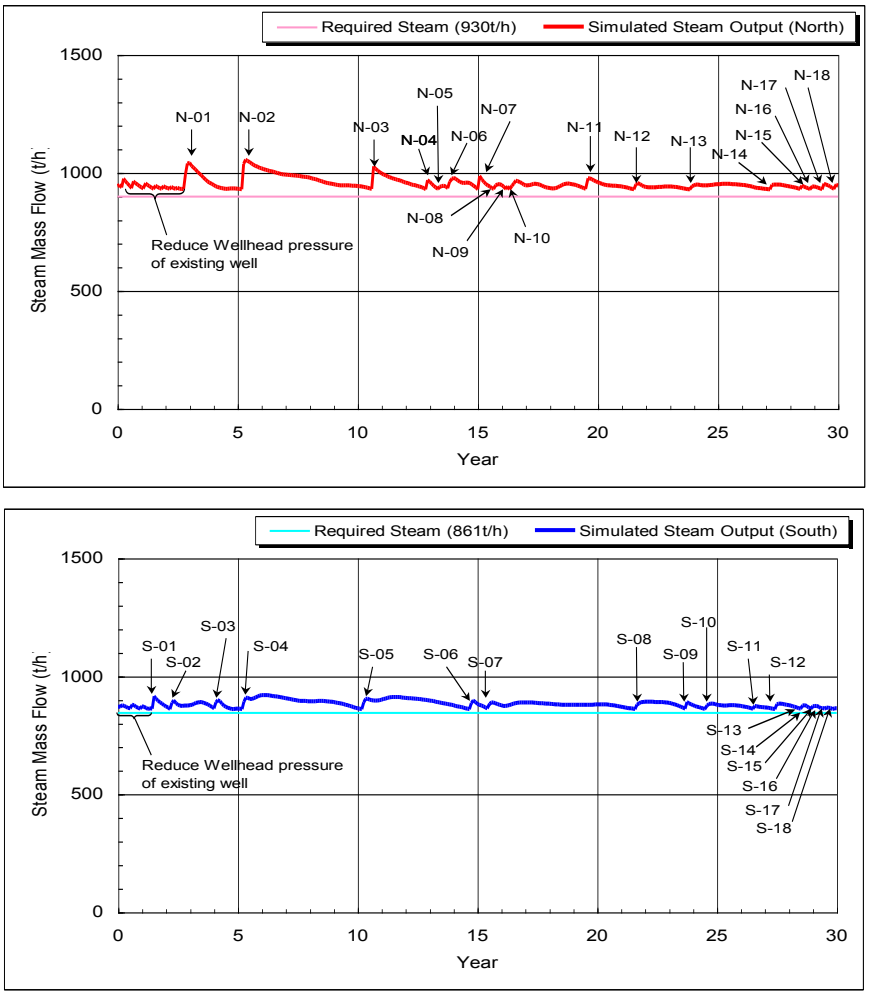

Figure 3. Forecast replacement steam for 227 MW.

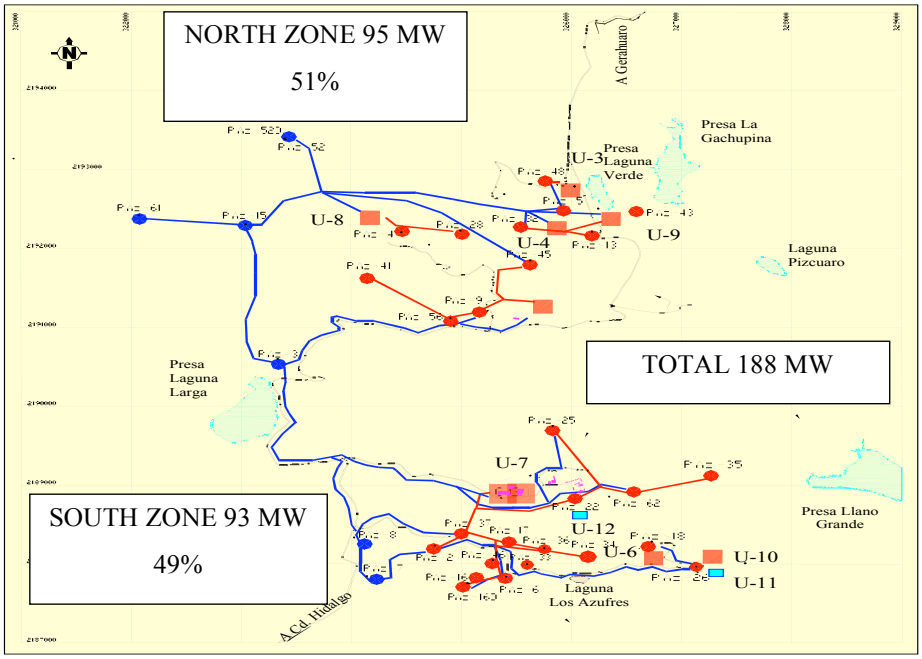

Figure 2. Installed capacity distribution for the Los Azufres Geothermal Field..

that is available on the surface a programme was designed in 2006 to define the strategy of expansion of the Los Azufres geothermal field in the short and medium term.

The proposal in the short term consists of replacement of seven backpressure units of 5 MW each, by two condensing plants of 50 MW and 25 MW. This proposal, named the Los Azufres III 75 MW, replaces units with high steam consumption by condensing units of low steam consumption, without drilling new wells.

2. Evaluation of the Reservoir

There have been several numerical simulation studies of of The Los Azufres geothermal reservoir carried out by external firms and CFE. The penultimate numerical simulation study was conducted in 2003 by the company GeothermEx, Inc. and updated in 2004. They used a dual porosity model in the simulator Tetrad.

Three scenarios were evaluated, two of them aimed at expanding the installed capacity in mining areas with untapped reservoir. Because the Los Azufres III project is to improve steam efficiently on the surface, the simulation scenario only describes these results:

• Conditions in current operation: producing 1650 t/h of steam equivalent to the current generation of 185 MW, injecting 85% to separate water injection wells in the north and 15% in the injection wells in the south.

For this scenario, the model indicates that the field can sustain the generation of 185 MW for at least 30 years with only 4 wells replenishment (without considering death of wells or inlay), drilled in the northern part of the field at a rate of approximately a well every 1.5 to 2 years, starting in 2010. It predicts a general trend of increase in enthalpy, especially in the south. Also predicted a decline in production increased in the north than in the south, because the permeability of the north is lower than in the south.

In April 2007, the Japanese company West Japan Engineering Consultants, Inc. carried out the Feasibility Study of the Los Azufres III Expansion Geothermal Project, whose aim was to assess the technical and economic feasibility of the approach of CFE called Azufres III consisting in the replacement of two backpressure units of 5 MW each and installing 2x25 MW condensing units each. The installed capacity would rise to 228 MW. The numerical model covered an area of 114 km^2, with an endogenous fluid extraction of 1791 t/h. The replacement wells were located in areas known and exploited. Figure 3 shows the outline of replacement steam.

The results indicate that the reservoir has the capacity to sustain the 227 MW installed over 30 years. The impact to the environment by the construction and operation of the Azufres III project is minimal because the sites for plants are located on flat land without use and without trees.

In conclusion, for purposes of Los Azufres III 75 MW project, which is to make more efficient use of the steam that is currently extracted, the reservoir is able to provide the necessary steam for 30 years, increasing the generation to replace backpressure plants by condensing plants of greater efficiency.

Table 2. Available Steam in the field.

SOUTH ZONE				*NORTH ZONE*			
Unit	Consumption of Steam t/h	Well	Qsteam (t/h) Jul-07	Unit	Consumption of Steam t/h	Well	Qsteam (t/h) Jul-07
						AZ-41	10
		AZ-17	39			AZ-56R*	53
U-2	68	AZ-34	43			AZ-67	23
		AZ-2A	50			AZ-69D	59
		AZ-1 A	48			AZ-66D	38
		AZ-06	25			AZ-65D	39
		AZ-16	11			AZ-57	20
		AZ-16D	20			AZ-28A	23
		AZ-22	101			AZ-28	75
		AZ-25	16			AZ-19	66
		AZ-33	42			AZ-4	23
		AZ-35	43	U-15 Y 16	180 Y 180	AZ-30	14
		AZ-36	16			AZ-09	10
		AZ-37	28			AZ-09A*	49
		AZ-38	84			AZ-9AD*	69
		AZ-46	50	U-5	68	AZ-45	20
		AZ-62	88			AZ-43	57
U-7 Y 13	440 Y 180	AZ-23	22			AZ-42	60
		AZ-18	73			AZ-48	45
U-6 Y 10	75 Y 75	AZ-26	67			AZ-32	48
						AZ-51	28
						AZ-13	68
				U-3, 4, 9 Y 14	65, 63, 76 Y 180	AZ-05	76
TOTAL	838		866	Total	812		973

Table 3. Actual steam balance in south zone.

Actual Scheme In South Zone		
Total Production	866	t/h
Consumption U-7 Y U-13	620	t/h
Consumption 3 x 5 MW	218	t/h
Mass Losses (1%)	8	t/h
Reserve Of Steam	20	t/h
Power	90	MW
% Reserve Of Steam	2.3	%

3. Expansion Project

The forecast for steam is presented in Table 2. The south zone of the field has enough steam to operate at the nominal capacity with a minimum support of 28 t/h, while the north zone will have a surplus of 161 t/h of steam due to acidification of the wells Az-9AD, Az-9A and AZ-56R in 2005 and 2006. These wells are operating at lower production rates, to reduce their rate of decline (marked with an asterisk in the table). In this balance the well Az-68D is not considered because it is scheduled for acid stimulation.

At present there are 7 backpressure plants of 5 MWeach with an average fuel economy of 13.7 t/h-Mw. Of these, three are located in the south. The balance of steam in this part of the field is shown in Table 3.

Table 4. Proposed scheme in south zone.

Proposed Scheme In South Zone		
Total Production	866	T/H
Consumption U-7 Y U-13	620	T/H
Consumption 1 x 25 MW	220	T/H
Mass Losses (1%)	8	T/H
Reserve of Steam	18	T/H
Power	100	MW
% Reserve of Steam	2.0	%

In order to make more efficient use of available steam Table 4 shows the balance of steam needed to replace 3 units currently operating for one condensing unit of 25 MW. It increases the

Table 5. Actual steam balance.

Actual Scheme In North Zone		
Total Production	973	t/h
Consumption U14, U-15, U-16	540	t/h
Consumption 4 x 5 MW	272	t/h
Mass Losses (3%)	26	t/h
Reserve of Steam	135	t/h
Power	95	MW
% Reserve of Steam	13.8	%

Table 6. Proposed scheme in north zone.

Proposed Scheme in North Zone		
Total Production	973	t/h
Consumption U-14, U-15, U-16	540	t/h
Consumption 1 x 50 MW	360	t/h
Mass Losses (3%)	27	t/h
Reserve of Steam	46	t/h
Power	125	MW
% Reserve of Steam	4.7	%

power to 100 MW without drilling new wells and the specific consumption is reduced from 13.7 t/h-MW (backpressure units) to 7.2 t/h-MW, which will allow for a more rationed operation of wells and a more efficient use of steam.

In the north zone are currently generating 4 backpressure turbinesof 5 MW each. The balance of steam in this part of the field is shown in Table 5. It has a steam production of 973 t /h of steam, which currently feeds 4 backpressure units of 5 MWeach, and three condensing units of 25 MW. In order to make more efficient use of available steam, Table 6 shows the balance of steam that would have to replace 4 backpressure units by one condensing unit of 50 MW. In this sector of the field the installed capacity can be increased to 50 MW without drilling new wells, making a more efficient use of steam and reasonable operation of most the wells.

4. Conclusions

The reservoir of the Los Azufres geothermal field has the capacity to sustain the generation of 228 Mw-h during 30 years.

Seven backpressure units of 5 MWeach, are replaced by two condensing units of 50 Mw and 25 Mw in order to increase the installed capacity from 188 MW to 228 MW.

With these replacement, the specific consumption is reduced from 13.9 t/h-MW to 7.2 t/h-MW, making a more efficient use of steam and consequently an rational operation of the wells avoiding a strong decline of the reservoir.

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