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Increase Geothermal Energy Generation Due to Matrix Stimulation Techniques in Mexico Geothermal Fields

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ABSTRACT

In Mexico and other countries worldwide, matrix stimulations have been done since several years ago, with the main objective of recover or increase the steam production and injection capacity in productions and injections geothermal wells. CFE (Comisión Federal de Eléctricidad), owner and operator of Los Azufres, Los Humeros, Las Tres Vírgenes and Cerro Prieto geothermal fields has done matrix stimulations in many wells, with excellent results in most of them. The geothermal energy contribution in the country energy matrix is around 2%, which is mostly generated by CFE, of the total generation by different technologies. This document presents the energy generation achieved by the increase of steam production rate in stimulations wells and its importance in the sustainable exploitation of geothermal fields.

1. INTRODUCTION

Geothermal energy in Mexico is almost entirely used to produce electricity, since direct uses are still under development and presently remain restricted to bathing and swimming. The net installed geothermal-electric capacity in Mexico until the end of 2018 is 951 megawatts (MWh). CFE produces almost 90 percent of the entire geothermal energy in the country. It operates four geothermal fields namely Cerro Prieto (570 MW), Los Azufres (225 MW), Los Humeros (95.7 MW) and Las Tres Vírgenes (10 MW). In order to maintain enough steam rate production to supply the generation power plants, CFE has applied several techniques that helps to leverage sustainably the geothermal resource, one of them is the stimulation technique as the matrix acidizing. This treatment consists mainly of injection a mixture of acid into the formation around the well, which aims to dissolve scaling or drilling mud that causes a decrease in the production or injection capacity of wells.

Several stimulations have been carried out since the year 2000, with excellent results in production wells, reducing the need to drill wells and contributing with the increasing energy generation that has placed to Mexico in the sixth place in installed geothermal generation capacity worldwide.

Figure 1: Geothermal fields in Mexico.

Presently, 38 stimulations have been carried out in the geothermal fields in operation by CFE, of which 67% have been performed in the Cerro Prieto and Los Azufres geothermal fields. The field with the least number of stimulations is the Los Humeros field, with only 3. In the Las Tres Vírgenes, even though it has the smallest number of integrated producing wells of the fields, 10 stimulations have been performed. However, on several occasions, they have been performed in the same well. This due to the nature of the geothermal fluids. On average there is an improvement of 145% in the steam production of wells. The geothermal field with highest rate of success is Los Azufres with an average of 190% increase in production.

2. WELL STIMULATIONS

Matrix acidizing is normally used for the removal of formation damage and also for increasing formation permeability in undamaged wells with low permeability, in both production and injection wells with successful results, done at the end of the drilling or later during the wells lifespan, by removing bentonite mud, silica or calcium scale. The formation damage can occur during any well operation such as during drilling, cementing, perforating, production, work-over and stimulation. The evaluation of formation damage is the most important factor in treatment design. This technique consists of injecting acid into the formation of the well at a pressure below the pressure at which a fracture might be open (Flores et al., 2005). The acid is injected into the well using a placement technique, i.e. drill pipe or coiled tubing in order to inject the acid directly in the feedzones.

The first production wells that were stimulated were in Las Tres Virgenes geothermal field in 2002 (LV-11 and LV-13). These wells were severely damaged by drilling fluid invasion. Since then, several acidizing jobs have been performed at the Los Azufres, Los Humeros, and Las Tres Virgenes geothermal fields, and Cerro Prieto (Flores and Morales, 2012). At present, the total number of acid jobs in production wells is 38, as shown in Figure 2.

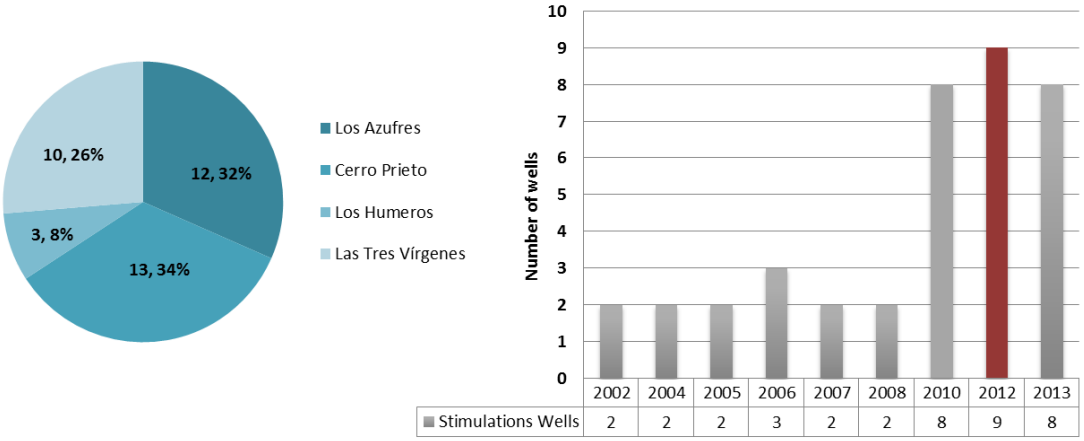

Figure 2: Acidizing jobs.

In 2010 and 2013, the greatest number of acid stimulations of production wells in Mexico was carried out and the success achieved during this period was more than 140% improvement in the production wells. The increase in steam production from stimulated wells varies considerably, from 33% to 600%, of the total operations carried out by 10% did not improve, was the case of 4 wells, two of them located in Los Humeros, one in Las Tres Vírgenes and one in Los Azufres. The highest increase in steam production in stimulated wells has been obtained in Los Azufres geothermal field with an average of 180% improvement per well in addition to the minimum number of failed stimulations. The results obtained from the total acid stimulation show that the greater improvement in production wells was obtained in wells damaged due to mud drilling, irrespective of the placement technique (drill pipe or coiled tubing).

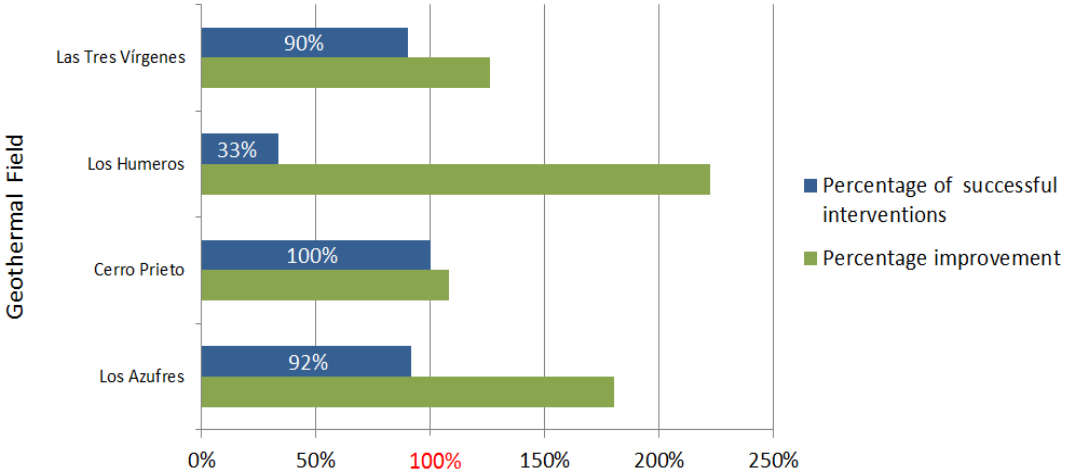

Figure 3: Steam production improvement.

The CFE has performed 4 acid stimulations in injector wells, all with the aim of eliminating silica mineral scale, thereby increasing the injection capacity. With the stimulation of injector wells, the rate of injectivity was increased by up to 140% compared to the conditions presented by the well previously, Figure 4. Failure to have a necessary steam arrangement capacity would result in restricting the production of wells, as wells as not sustainably recharging to the reservoir, which would be reflected directly in the generation of energy.

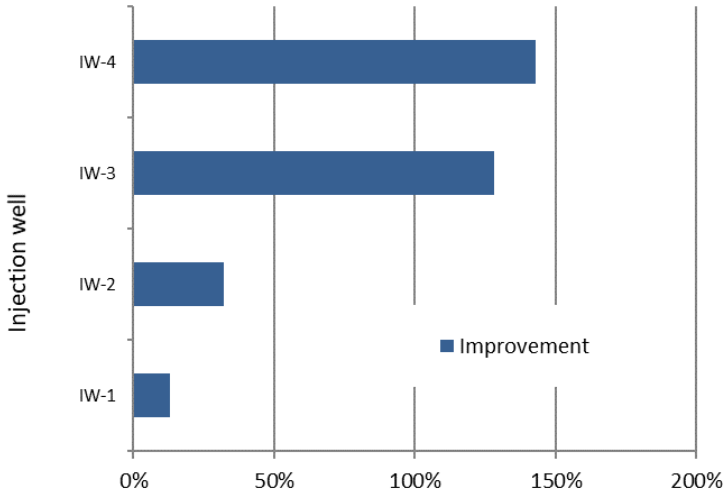

Figure 4: Injection index improvement.

3. STEAM PRODUCTION INCREASE

As mentioned above in the last chapter, the increase in steam production due to matrix stimulation has been very significant. The stimulated wells have also the advantage of being integrated quickly into the steam supply system in the geothermal fields. Thus, the benefits of this treatment can be observed immediately.

At the beginning of 2003, the first stimulated wells were integrated to the supply system, in sequence until 2013 where most of the successfully stimulated wells were integrated, as shown in Figure 5.

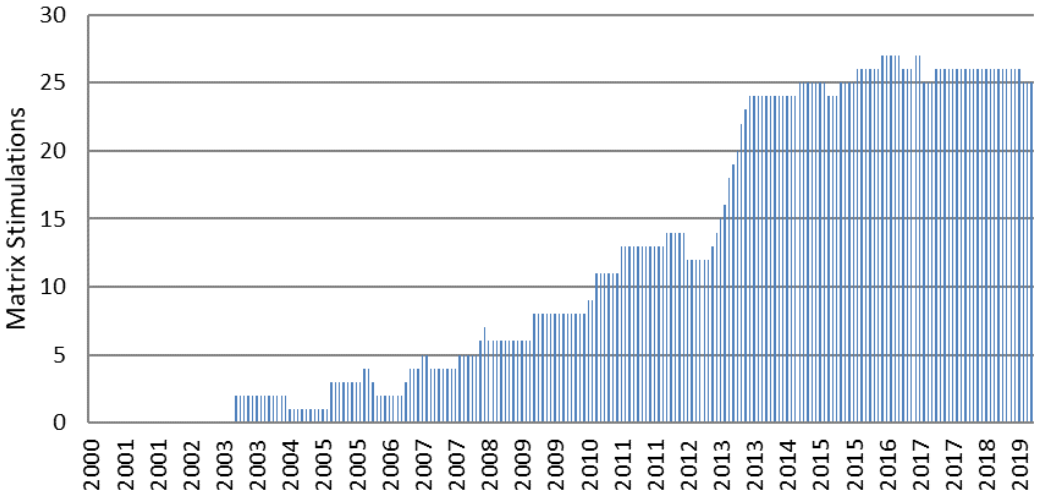

Figure 5: Injection index improvement.

In order to analyse the improvement with this technique, a projection of the production from 2010 to 2018 was done to obtain the steam rate without matrix stimulation in each well, taking into account the average declination of each geothermal field and the measured steam production. The results shown that in 2018 the steam production rate of 241 t/h, whereas with the matrix stimulation, the measured steam production in December 2018 was 656 t/h. This show a 160% increase in the wells steam production, as shown in Figure 6.

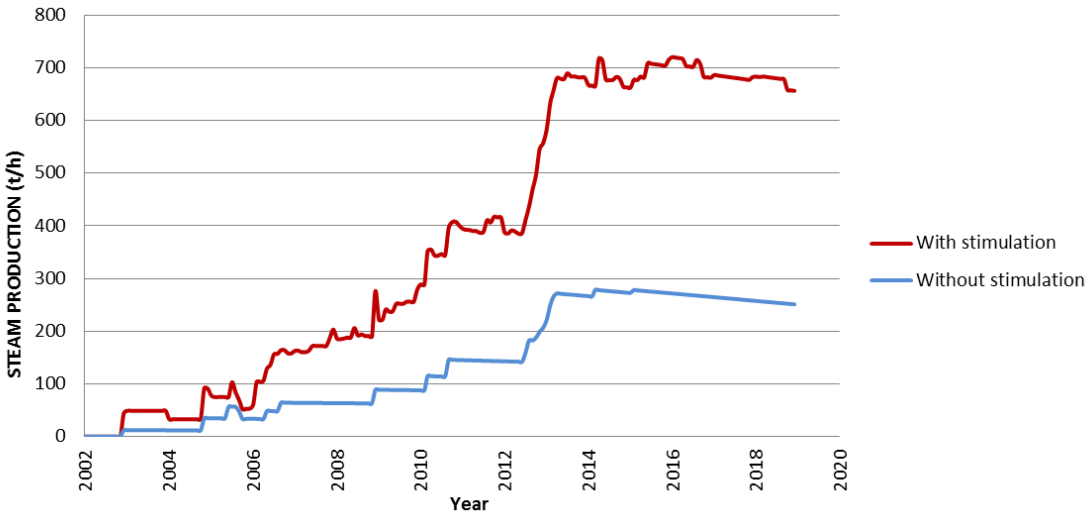

Figure 6: Projection and measurement steam production.

The steam production that accumulated since 2010 to 2018 is around the 53,668,792 t (Figure 7), while the real increase in production is by 33,570,817 t in this period. These wells had been integrated right after the treatment. This could represent more than 10 years of lifespan, that in some cases, these wells could be now out of the steam supply system due their low productions.

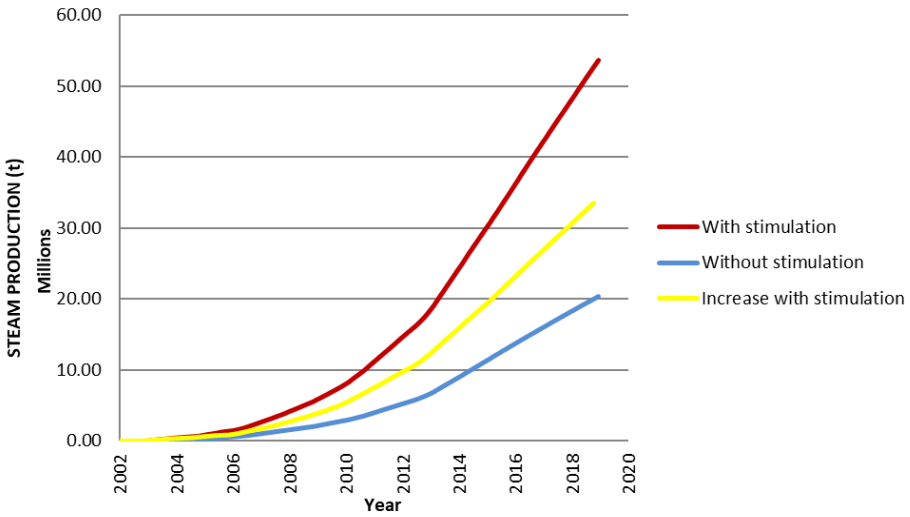

Figure 7: Projection and measurement acummulated steam production.

4. ENERGY GENERATION AND ECONOMICAL BENEFITS

The main objective to improve this technique for geothermal wells is to achieve or maintain enough steam rate to power the plants, to extend the lifespan of the wells, and to modify the thermodynamics or geochemistry conditions in order to be able to used fully the geothermal resource, and with it the intention of having an important participation in to the matrix energy generation of the country. The geothermal energy participation into the energy matrix generation in Mexico is it 1.3% that represent 5375 GWh, in 2018, Figure 8. The CFE's installed capacity is 900.7 MWh, installed in four geothermal fields, the steam is supply by more than 200 production wells, with an average steam rate of 25 t/h.

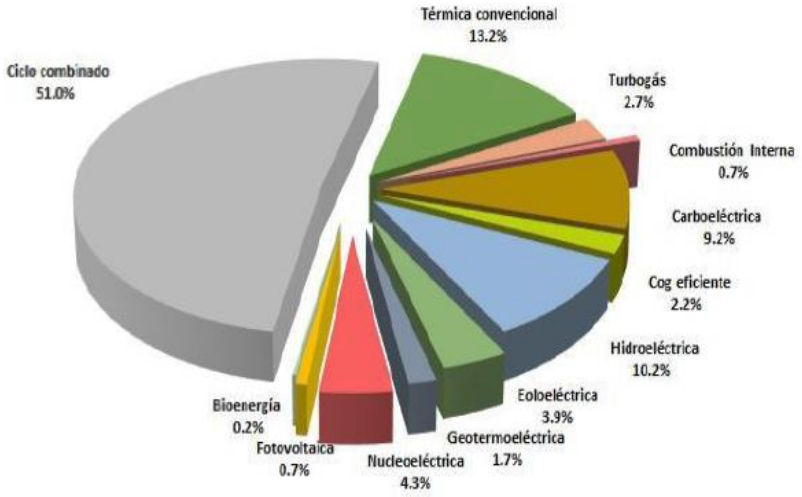

Figure 8: Matrix energy generation in Mexico (PRODESEN 2019-2033).

The results of the matrix stimulations are able to improve the production conditions in geothermal wells and therefore to increase or maintenance the energy generation. This improvement represented an energy generation increase, considered only the stimulated wells, of 52 MWh at the of 2018, the accumulated generation by the wells stimulated is 6708 GWh since 2010. This generation represents more than the total geothermal energy generated in one year in México, according with the data during 2014, 2015, 2016 and 2017, the generated geothermal energy was of 6,000, 6,331, 6,150 and 6,041 GWh, respectively.

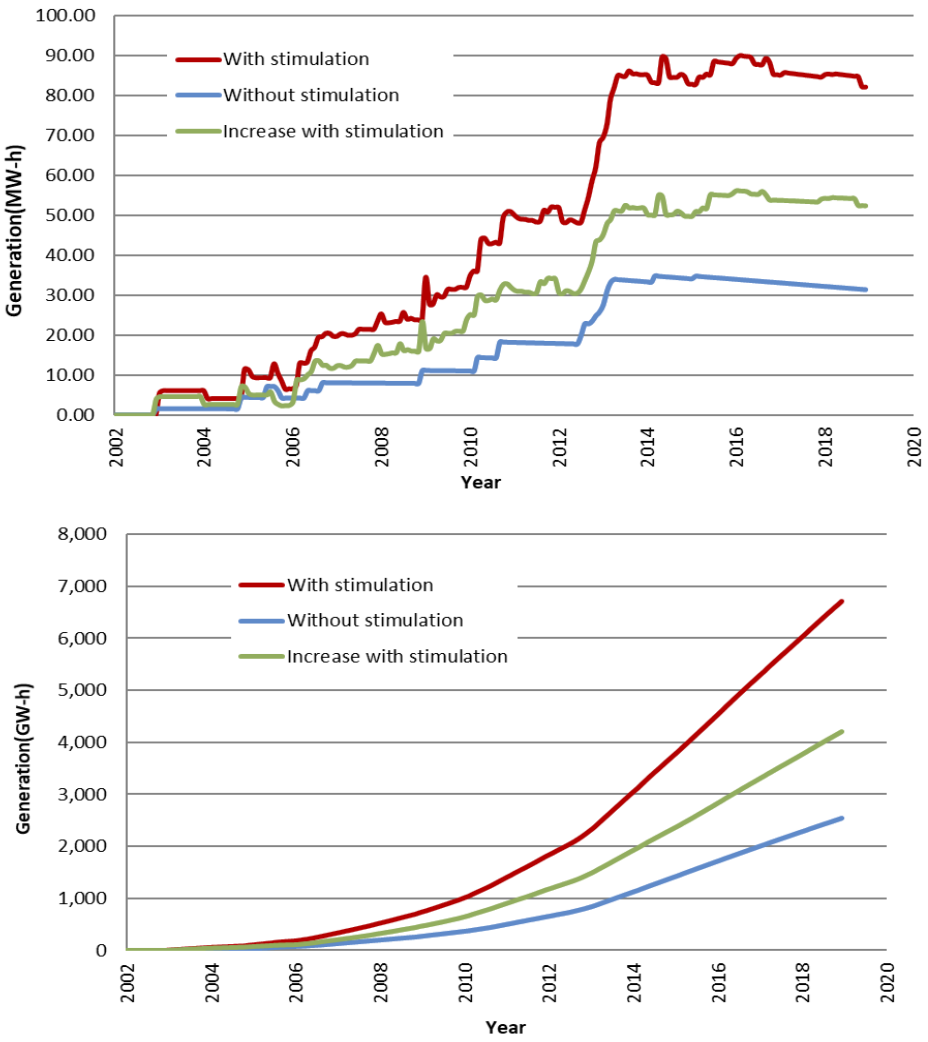

Figure 9: Increase in energy generation.

On the other hand, in economic terms, the application of this technique has increased the income of energy sales. In 2018, if the steam production behaves like in the projection, the revenue for the energy produced by the steam of this wells would be approximately of 6,651 thousand USD. This is due to the excellent results that could be achieved in 2018 from energy sales by 170% more or 18,059 thousand USD.

This analysis considers the average marginal price of the energy in the market in Mexico per node corresponding to each geothermal field indicated by SENER, Mexican Secretary and Nacional Commissions of Energy. As well a power plant factor is taking in count by each geothermal field as show Table 10.

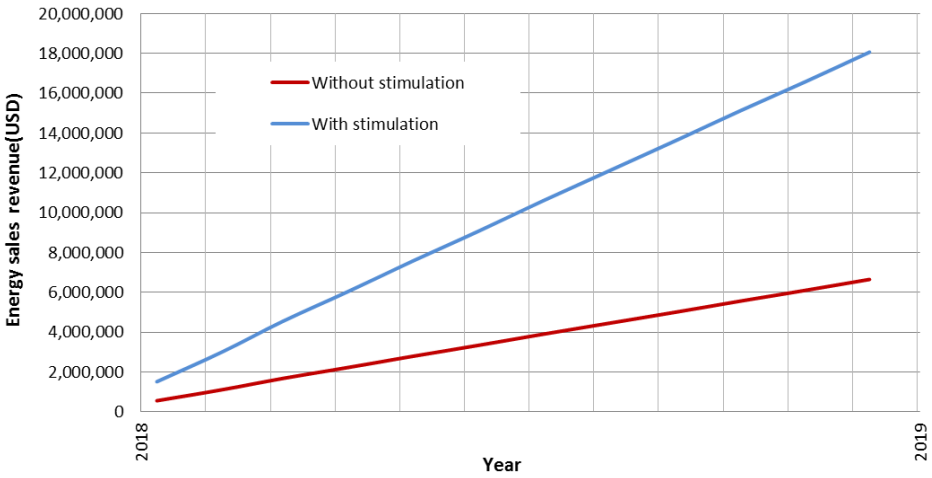

Figure 10: Energy sales revenue in 2018.

Table 1: Considerations taken for analysis.

Geothermal field	Node	Price	Power plant factor
Los Azufres	Carapan	38.67	75%
Las Tres Vírgenes	Mulegé	21.57	54%
Cerro Prieto	Mexicali	29.83	70%

5. CONCLUSIONS

Matrix acidizing is normally used for the removal of formation damage and to increase formation permeability in undamaged wells with low permeability, in both production and injection wells.

38 stimulations have been carried out in the geothermal fields by CFE, with an improvement average of 145% in the steam production of wells, the geothermal field with a higher success rate is the Los Azufres with an average of 190% increase in production. Of the total operations carried out, 10% did not improve. With the stimulation of injector wells, the rate of injectivity was increased by up to 140% compared to the conditions presented by the well previously.

The steam production accumulated since 2010 to 2018 is around the 53,668,792 t, while the real increase in production is by 33,570,817 t in this period. The revenues by the energy produced by the steam of this wells, would be approximately 6,651 thousand USD, due to the excellent results which resulted in 170% higher income.

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