Geothermal power plants in Italy: increasing the environmental compliance

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ABSTRACT

The attention to the environmental issues of industrial activities has been growing in the last decades. Enel Green Power has devoted a large part of its technological developments to the environmental compliance of its geothermal power plants with remarkable success, confirmed by the obtainment of the ISO 14001 and EMAS certifications since 2005 and 2010 respectively.

The backbone of this effort, in the framework of a continuous improvement strategy, has been the adoption of the AMIS technology for the abatement of mercury and hydrogen sulfide emissions (Figure 1). At the end of 2012, 28 generating units out of 34 are equipped with AMIS plants: about 85% of the emitted NCG are thus treated, leading to a substantial improvement of the air quality in geothermal areas. The remaining 6 more AMIS plants will be built within 2014, while two more AMIS plants will equip the Bagnore 4 power plant (two 20 MW units), leading to 100% application of this treatment.

Figure 1: Picture of the AMIS plant installed in Piancastagnaio 3 power plant.

Other main issues that have been addressed are constituted by the reduction of noise and drift emissions from the cooling towers, the integration of the power plants and steam pipelines in the Tuscany countryside landscape, the construction of dedicated trails around the geothermal installations so as to create touristic points of interest, and the reduction of steam emissions during the shut-downs.

The environmental performances of the power plants are controlled both directly with periodical measurements of the emissions and indirectly by means of multi-year environmental monitoring plans that include networks of air quality and microseismic stations, analyses of waters, vegetation, lichens and soils, carried out by Enel Green Power. The Regional Environmental Authority of Tuscany (ARPAT) receives and checks the data sent by Enel and is in charge of additional controls on the emissions and air quality monitoring.

1. INTRODUCTION

Geothermal energy is a Renewable Energy Source; however, its environmental impact, depending on the characteristics of the geothermal reservoir, may in some cases be not negligible.

The main concerns derive from air emissions, caused by non-condensable gas (NCG) being vented to the atmosphere and drift emitted from the cooling towers, noise emissions and visual impact on the landscape.

The environmental compliance of the power plants is a key issue for the social acceptability of any geothermal development, even in the Italian situation where the industrial operation of power plants fed by geothermal steam dates back to almost a century ago in Larderello area (Figure 2).

Figure 2: Mr. Ginori-Conti lights 5 lamps using geothermal steam, 1904.

Enel Green Power (EGP), the company of Enel Group devoted to the RES utilization, currently operates 722 MW of geothermal gross generating capacity in Italy, with 34 units all fed by high enthalpy resources (dry steam or flashed steam), plus 46.5 MW of binary power plants in the United States, fed by low enthalpy resources (brine in the 150-160°C range).

EGP has devoted many efforts towards the environmental improvement of both new power plants being built and existing power plants already in operation, with notable capital expenditures, in particular since the early 1990s.

The present paper describes the main results so far obtained and ongoing activities.

2. NCG TREATMENT

The main pollutants contained in the NCG emitted from geothermal power plants are hydrogen sulfide (H_2S) and mercury (Hg).

The former, although not dangerous or health threatening even in the long term at the low air concentrations that occur nearby the power plants, is characterized by a characteristic smell of rotten eggs that can be perceived even at very low concentrations, around 7 ppm. Hence, H_2S can cause a nuisance to the population over this threshold.

Mercury is present at very low concentrations in geothermal fluids, but its environmental mobility and high toxicity make it necessary to abate as much as possible the quantity emitted, especially in particular areas, such as Mount Amiata, already contaminated by mercury compounds deriving from the previous mining activity (mercury ore extraction and mercury production).

H_2S abatement technologies for geothermal generation are sufficiently developed; however, the characteristics of Italian power plants (high NCG gas content, ranging from 1.5 to 9% with an overall average of around 4.4%; direct-contact condensers; high CO_2 content, with consequent low calorific value of the NCG; small size of the power plants, typically 20 installed MW, which are remotely operated) make either technically or economically not suited the processes used elsewhere (Stretford, LO-CAT® and RT-2®, or burner-scrubber).

Hence, Enel developed (Baldacci and Sabatelli, 1997) and patented (Baldacci, 2001) a process tailored for the characteristics of its power plants, which was named AMIS (acronym for “Abatement of Mercury and Hydrogen Sulfide” in the Italian language).

Preliminary studies started in the early 1990s and were followed by laboratory tests on mercury sorbents and catalysts for hydrogen sulfide oxidation; a pilot plant using a side stream of a geothermal power plant was then used to demonstrate the feasibility of the process between 1997 and 1998. The design and construction of the first commercial unit (installed on a 20 MW power plant in Mt. Amiata area, Bagnore 3) followed, which commenced operation in early 2002. Mt. Amiata area was chosen for the first application, as mercury concentrations in the steam and environmental concerns in the area are both among the highest.

AMIS technology was first disclosed at the last 2005 WGC (Baldacci et al., 2005), whilst a more comprehensive description and a summary of the operating experience were the subject of a subsequent publication (Sabatelli et al., 2009).

In a typical AMIS plant (Figure 3), NCG exhaust from the centrifugal compressor (which is used to maintain vacuum in the direct-contact condenser) is cooled by direct contact with water in a packed column. Mercury is then adsorbed in a fixed bed of sorbent, whose lifespan is well over 5 years. A regenerative heat exchanger raises the NCG temperature so as to allow catalytic oxidation of hydrogen sulfide to sulfur dioxide (SO_2) in a fixed bed of catalyst. After a first cooling in the regenerative HEX, a scrubber and a packed column cool down the NCG and at the same time sulfur dioxide is absorbed in the cooling water as sulfites. Treated NCG are eventually vented through the cooling tower, where mixing with air occurs.

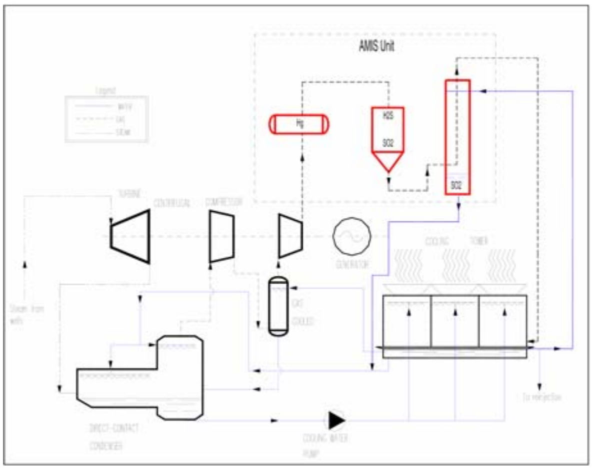

Figure 3: Simplified scheme of the AMIS process.

Sulfites, which are partially oxidized to sulfates by oxygen in the cooling water, tend to make the cooling water acidic. Depending from the ammonia content in the inlet steam, caustic soda (NaOH) must thus be added in order to prevent very low pH values. However, a target pH value of 6 to 6.5 can be maintained, so as to increase hydrogen sulfide partitioning in the direct-contact condenser and reduce the amount stripped from the cooling towers.

Typical overall hydrogen sulfide abatement efficiencies range from 80 to over 90% (near 100% abatement is obtained in the NCG).

As of December 2012, 26 AMIS plant are in operation. The first 2 were built in 2002 and 2003; 17 more (one of which features a double train of equipment) were added between 2005 and 2010 as a voluntary commitment by Enel, as no emission limit was overcome. Four additional AMIS plants were built between 2010 and 2011 to new or renewed power plants, as all authorizations for new installations, released after an EIA procedure, require the power plant to be equipped with an AMIS abatement plant.

28 generating units out of 34, accounting for 85% of the overall hydrogen sulfide emissions, are thus currently equipped with AMIS technology, leading to a substantial reduction of the odor nuisance.

The remaining 6 units will be also equipped with AMIS plants in the year 2014, thus completing the installation program on the existing power plants. The new Bagnore 4 power plant (Figure 4), with two 20 MW units, will also be operating at the end of 2014 in the Mt. Amiata area and will feature two additional AMIS units.

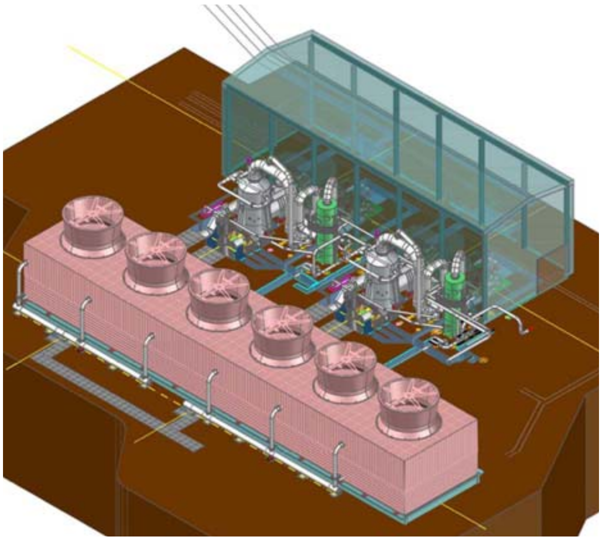

Figure 4: Rendering of Bagnore 4 power plant.

Finally, unabated emissions are reduced increasing the availability of generating units and reducing the shutdowns and the consequent steam venting to the atmosphere. Steam redirection among interconnected power plants is also used to this aim.

3. AMMONIA EMISSIONS

Ammonia is contained in geothermal steam and, in unabated plants, most of it is emitted from the cooling towers. Even if ammonia is not strictly a pollutant, its emissions are undesirable as a precursor of particulate matter.

AMIS power plants use the natural ammonia content to neutralize all or part of the acidic sulfur species deriving from hydrogen sulfide oxidation, helping to reduce the caustic soda requirements (driven by the H_2S/NH_3 ratio in the inlet steam).

The lower pH of the cooling water with respect to an unabated situation prevents ammonia stripping in the cooling towers, so that its emission are largely reduced, and only 10 to 20% (vs. 80 to 90% unabated) of the inlet ammonia is released to the atmosphere. AMIS has thus a beneficial side effect on ammonia emissions.

However, in Bagnore field the ammonia content (and the NH_3/H_2S ratio) of the steam is so high that the reduction of ammonia emission given by the AMIS plant is only about 50%.

Enel has only one 20 MW power plant operating in Bagnore field (Bagnore 3); in order to release the authorization of an additional power plant (Bagnore 4, with two 20 MW units), a specific requirement of ammonia abatement was asked by Tuscany Region.

Enel Green Power, with the support of the Engineering and Research Division, modeled and successfully tested in Bagnore 3 a method to achieve the same level of ammonia abatement of the other power plants. This method consists in the addition of sulfuric acid to the cooling water, so as to lower its pH to 6÷6.5: ammonia is combined as sulfate and its stripping prevented.

4. COOLING TOWERS

Wet cooling towers of the induced draft type are the standard solution for heat rejection to the environment from steam-fed geothermal power plants.

The main issues associated with this type of equipment are the drift (liquid droplets entrained by the air flow) and noise emissions from the mechanical equipment (motors, gearbox and fans).

Drift is of particular importance, as the cooling water is made up of concentrated steam condensate, thus containing many chemical species (including ammonia and/or sodium sulfite and sulfate deriving from hydrogen sulfide abatement in the AMIS plant), among which boric acid.

Drift eliminators are used to reduce drift; state-of-the-art drift eliminators are used in the most recent cooling towers and to retrofit existing ones, with typical performances that prevent less than 0.002% of the circulating water flow to be emitted (as a reference, for cooling towers built in the 1980s and 1990s the drift allowance was 0.008%). For a typical 20 MW unit, the maximum water flow is 6,000 m3/h, so that the maximum drift can be estimated at 120 L/h.

A substantial noise reduction has been obtained through the use of state-of-the-art gearboxes, specifically designed for the application in cooling towers, and low-noise fans. In particular situations, floating nets can be installed in the cooling water basin to reduce the noise emission deriving from the splash of the water.

5. LANDSCAPE AND TOURISM

Geothermal power plants are typically distributed on the territory, due to the presence of well pads and gathering/injection systems in addition to the power plant equipment and building.

Site selection for well pads and power plant, as well as pipeline routes, are of paramount importance for limiting the visual impact. An additional mitigation can be obtained by the choice of suitable colors, which make it possible to "blend" the installations with the surrounding landscape.

An example of the results that can be obtained is given by the most recent 20 MW power plant that went in operation (in the last quarter of 2010), Chiusdino 1 (Figures 5 and 6). This plant is situated in the Travale – Radicondoli area, South-East of Larderello. The power plant area was obtained as an extension of an existing drilling pad, with very limited visibility from the nearby village of Chiusdino. A green color was used for the buildings and the equipment located outside the powerhouse to blend with the vegetation.

Figure 5: Picture of Chiusdino 1 power plant.

Figure 6: Chiusdino 1 power plant from another perspective.

The steam pipelines in Travale – Radicondoli area, where most of the recent geothermal development occurred, are built positioning them within trenches that prevent their visibility even from adjacent roads (Figure 7); naturalistic engineering techniques are used to complete the work.

Figure 7: Trenched steam pipelines.

Geothermal installations are used as means to attract tourism in some strategic locations, with the construction of walkways provided with equipment on show and descriptive tables. Together with natural manifestations and the geothermal museum in Larderello, about 77,000 people were attracted and visited Larderello area and surroundings in 2012.

6. ENVIRONMENTAL CONTROLS

Enel Green Power carries on a dedicated environmental monitoring plan for its geothermal installations, both with continuous measurements and periodical campaigns.

A network of microseismic stations is used to detect any seismicity that might be generated by the injection activity.

Air quality stations are located near the villages of geothermal areas to measure hydrogen sulfide and mercury concentrations in the ambient air.

Yearly samplings and analyses are carried out in order to measure the emissions of the main pollutants and to monitor AMIS efficiencies.

Periodical campaigns maintain under control the soil vertical movements (precision leveling), the surface water quality (analyses of water sources and watercourses), air quality (mobile station), etc.

As a general rule, the status of the environment around power plants is monitored and compared with the situation existing before the plant was put into operation, both with direct measurements (soil, vegetation) and indirect methods (lichens used as biomonitors).

The results of the environmental control activities are sent to the Regional Environmental Agency (ARPAT), which is in charge of additional controls carried out directly by their personnel.

Moreover, additional general studies related to aquifer interaction, epidemiological surveys and the like were commissioned by Tuscany Region to Universities or Agencies.

All evidence so far reached suggests that geothermal energy utilization has a very limited impact on the environment and its sustainability is beyond any reasonable doubt.

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