Renewable Energy 74 (2015) 379–389

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Data bank

The web-oriented framework of the world geothermal production database: A business intelligence platform for wide data distribution and analysis

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ARTICLE INFO

Article history:
Received 13 August 2013
Accepted 14 August 2014
Available online 7 September 2014

Keywords:
Geothermal energy
Power generation
Direct uses
Installed capacity
Data organization

ABSTRACT

The Global Geothermal Energy Database of the International Geothermal Association (IGA) is an internet-based platform providing access to the world geothermal production data. This platform is unique for the geothermal sector, and provides an excellent tool for showing geothermal use in the world and promoting the development of geothermal energy. The platform is also an important example of organization and access to widely distributed data, since it allows analyzing, synthetizing and quickly interpreting stored data.

The global and country-specific information regard both electricity generation and direct use applications. The platform, which has been built using an open-source Business Intelligence application and can be accessed through the IGA website, allows to access, navigate and organize information in various ways. Data lists related to geothermal fields and plants, direct uses, geothermal turbine manufactures and geothermal companies can be accessed, aggregated and filtered, producing reports, charts and maps. Aggregation and filtering options synthetize and organize data for direct use, power plants and installed capacity by region, category and operative status. The mapping tool, providing geothermal fields location, power plants and direct uses geographical references, allows also map browsing, and to zoom, to measure distance, to pan and to query for further information. The chart analysis produces pie charts and bar diagrams of data, dynamically sorted and aggregated.

1. Introduction

Geothermal energy, literally the thermal energy of the earth, is often used as a term to refer to the conversion of earth's thermal energy into electricity. Geothermal energy has provided commercial base-load electricity around the world for more than a century. Beside large geothermal plants for power production and/or district heating and cooling, which rely on medium- and high-grade hydrothermal systems, many shallow, medium-to-low-grade resources proved useful for direct uses of geothermal heat in a number of applications [1–3]. Advanced and modern applications are also attracting interest (see, for example [4]). Nowadays about 70 TWh of power and 0.2 EJ (excluding heat pumps) of heat are produced every year in the world thanks to geothermal energy [1,2]. The long-term potential of geothermal energy is the opportunity to develop technologies for sustainable heat extraction from large volumes of accessible hot rock anywhere in the world. Optimal generation would require the new heat transfer enhancement methods (see for example [5–9] and references therein). The International Energy Agency Geothermal Roadmap [10] envisions that by 2050 geothermal electricity and heat generation could reach 1400 TWh and 5.8 EJ per year, respectively. This would be achieved also by development of enhanced geothermal system technology [11–13] references therein.

Many attributes of the geothermal energy, namely its widespread distribution, availability 24 h a day all year round, its base-load capacity without the need for storage and flexibility, small footprint, and low greenhouse gas emissions, and recognized, even critically, by many documents (e.g., [14–18] references therein). However, both electricity and thermal production from geothermal resources are not very advertised, and the geothermal sector lacks

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http://dx.doi.org/10.1016/j.renene.2014.08.036
0960-1481/

the necessary knowledge and the support from potential stakeholders. An open geothermal energy information platform enables geothermal energy analysis and a widespread public use.

Some countries or associations have developed databases and tools to provide geothermal production data on internet. The large part of available information is in the form of maps of power production plants, reports and data lists. This means that data are not organized, categorized, and accessible for operational insights and decision-making. Most maps and data are available on a national base (e.g., NREL geothermal maps for USA available on http://www.nrel.gov/gis/geothermal.html) and only a few of them cover the world (e.g., the map of the largest countries by geothermal electricity production of "Maps of World" whose data sources is not specified). Maps of geothermal production for direct uses are seldom available (one exception being the GeoHeat Center Maps for USA, on http://geoheat.oit.edu/dusys.htm), and data are difficult to retrieve and seldom classified.

The internet-based platform managing the world geothermal database of the IGA (International Geothermal Association) originated from the need to provide power and heat production data of geothermal plants around the world as a web application, featuring a 'learning section' that enables users to build capacities to use this information for feasibility assessments, policy making and market development.

Geothermal data are periodically collected by the IGA on the occasion of the World Geothermal Congresses (WGC), organized every five years, when each country is invited to provide updated data regarding geothermal uses, both for power and thermal production. A template is circulated about one year before the congress, and data are collected and organized on a worldwide base. All data, also for the previous congresses, are available in the proceedings published by the IGA and provided by the geothermal conference paper search engine, which can be accessed on the IGA website. Beside the country update every five years, geothermal data are collected and organized in overview reports, written on the occasion of WGCs or for the IGA Newsletters. When updated information arrives from IEA (International Energy Agency) GIA (Geothermal Implementation Agreement), EGEC (European Geothermal Energy Council), or directly from public announcement by developer, data are also updated in the repository, and therefore on the platform. The main source of the geothermal power production and direct uses data used here are, respectively [1–3], and references therein.

In this paper we (1) describe the IGA world geothermal data collection providing a brief description of the basic concepts, (2) provide an overview of the database architecture, including the structure and the database design, and (3) explain the main queries that have been developed, the performed calculations and comparisons, and the available lists, maps and charts. The freely-accessible platform here described is able to manage geothermal geo-spatial data and a wide dataset, and to combine real-time analysis for immediately, internet-based insight.

Geothermal energy has produced electricity and thermal energy for many decades now, and many data with them: for the first time it is possible, thanks to the described database and Business Intelligence (BI) tools, not only to organize and easily retrieve data, but also to analyze them in detail.

2. Data content, classification and terminology

The first issue we had to face was classification. The choice was mostly driven by the choice of the data source, i.e., by IGA data format defined by the country update template. Please note, however, that geothermal reporting terms are not widely recognized and different countries and associations classify and record different kind of data (e.g. [19], for details). However they share some common characteristics, and for the scope of the present work the classification refers to the following basic elements: (i) Geothermal Fields and (ii) Geothermal Plants (both for electricity), and (iii) Direct Uses (of the heat). We describe here the main choices and explain the terms used in the work.

2.1. Geothermal field

"Geothermal Field" is a geographical definition, often used for indicating an area of geothermal activity at the earth's surface. The geothermal fields refer to the presence of hot fluids at depth, within the so-called reservoir, which may provide surface manifestations, especially when they are very hot and/or shallow. However, sometimes the geothermal field does not exhibit any surface manifestation, and in general the definition indicates the area at the surface corresponding to the geothermal reservoir below.

Following the nature of fluids in the reservoir, the geothermal systems and related fields are usually classified in the geothermal community under two main categories: water-dominated and vapor-dominated geothermal systems. In water-dominated systems the geothermal fluid in the reservoir is liquid water (under pressure high enough for keeping high temperature fluid in liquid phase). Some steam may be present, generally as discrete bubbles. These geothermal systems, with a temperature in the range of 125–250 °C (and in some exceptional cases over 250 °C), are the most widely distributed in the world. When brought to the surface and depending on temperature and pressure conditions, they can produce hot water, water and steam mixtures, wet steam and, in some cases, dry steam. In vapor-dominated systems the reservoir fluid is mainly high temperature vapor. They normally produce dry-to-superheated steam, with a very high energy efficiency. Unfortunately these systems are rare, the best-known of which are Larderello in Italy and The Geysers in California. This rather wide-scope classification can be further improved, adding details on the nature of fluids (e.g., one-phase versus two-phases systems, high enthalpy versus low enthalpy systems and so on).

The platform here described does not follow this classification, since it is implicit in the technology used to exploit the different kind of systems. It is the power plant type, as described below, which drives the organization of data. We have kept the geographical characterization, here defined by the term *Geothermal Field*, and only for the electricity production, since the direct utilization of heat refers to very different geothermal resources, and they are too scattered: the geothermal field has little meaning in this regard.

We distinguish (and then map) *Present* and *Future* Geothermal Fields, meaning respectively identified existing fields, having plants in operation, and fields in development, where projects are at different stages of realization. Being this concept strictly linked to electricity, the fields are characterized by the two most important exploitation parameters, i.e., *Installed Capacity* (in MW_e) and *Produced Energy* (in GWh). Each geothermal field is also associated to the operating company (entitled of the mining rights), which is called *Field Owner* in our application.

2.2. Geothermal plants

The technology (and classification) of the geothermal plants for electricity generation is strictly related to the thermo-dynamical state of the geothermal reservoir fluid. A more extensive description is given in Ref. [20], but we provide here a brief explanation of the used terms.

We have identified the turbine as major component characterizing the plant manufacture. Turbines, which are moved by vapor,