SYSTEM APPROACH TO GEOTHERMAL FIELD DEVELOPMENT

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INTRODUCTION

Geothermal energy will play an important role. Thanks to the great endeavors of those engaged in the geothermal field development in Japan, it has become possible to generate 50MW/hr of electricity per unit field. Up to this day, as is often the case with its stage in the cradle, the main purpose has been to produce electricity from geothermal steam. The target of exploitation has mainly been the area by surface geological survey and the reservoirs are located not deeper than 1500 meters.

The technology for geothermal resource development necessitate full application of every essential technique in order to cope with the various types of objective geothermal resources, and, since it has direct influence on the profitability of investment, it needs to be evaluated from an overall viewpoint. The evaluation, at the same time, must be carried out efficiently, invoking various effective methods.

Therefore, it is expected to develop a simulation model which gives rational data for a judgement in working out strategies, such as the scale of the exploration, installation of utilities and schedules of investment and development. With a view to it, the model should be able to simulate both physical and economical phenomina through the life of the geothermal field, that is, from the beginning of exploration to development and utilization. It also should at once determine the optimum conditions the static and dynamic characteristics of the reservoir, the depth and the number of production and injection wells, the fittest layout and specifications of the site including surface facilities, the behavior of pressure, enthalpy and other behaviors of the geothermal fluids flowing from the bottom to the head of the well and the costs associated with exploitation, production and operation.

The purpose of this study is to develop simulation models for optimizing the scheme from exploration to utilization and to compose simulation programs for a digital computer.

CONCEPTS

Generally system approach seems to be advantageous when applied to a large scale project such as the geothermal field development. The process of the study on geothermal resource development system starts with planning, selection, analysis and composition of the system. Design of a system, reliability analysis and evolvement of the composition accompany the process, employing various techniques of simulation, optimization and computation, Thus the development pattern for economical operation is drawn - how should geothermal energy be extracted from a specific reservoir and utilized at the lowest cost or with the best recovery rate with economy assumed to be of second importance?

Hitherto the main concern of geothermal resource development in Japan has been geothermal steam production for generation of electricity. Each essential technology for exploration, drilling, development, production, transportation and generation of electricity is open to the charges of being rather separate and desultory. Utilization of geothermal energy other than for electricity generation has been mostly for recreation and therapy in baths and spas at low temperature levels, but recently there has been a trend toward multipurpose usage of hot water. And the target of exploitation is not necessarily the area of shallow zones; every type of geothermal reservoir is now explored.

It is important to categorize the results of research work on each elemental technique, to make up a formula for geothermal exploitation and development and for effective utilization of various types of promising resources macroscopically, to develop the knowhow for establishing the most appropriate conditions for exploitation and development, to rearrange different priorities for future development, and to point out hardware items which should be investigated and tried out.

A model for exploration of large scale deep geothermal resources should be able to simulate the layout, depth, number of production and injection wells, well head pressure, and steam composition and enthalpy of hot fluids, to estimate drilling and operating costs, discharge of hot fluid and the option and layout of surface facilities and to print out the optimum condition of the system. This is of great significance in determining the most efficient system for geothermal resource development.

OUTLINES OF SUBSYSTEMS

The outlines of each subsystem which is the component of the total system for geothermal field development are explained below.

(1) Subsystem for exploration investigation

Preliminary surface and subsurface surveys are the first step taken. Surface sur-vey is classified roughly into two categories, one of geological structure and the other of anomalies caused by the existance of geothermal fluid. The former consists of geologic surveys and gravity, magnetic and seismic prospecting. The latter includes surveys of hydrothermally altered rock, electrical conductivity surveys, geochemical surveys, geothermal gradient surveys, heat-flow determinztions and microearthquake measurements. Meanwhile subsurface survey comprizes structural boring, drilling of exploratory and reinjection testing wells, geological and geochemical logging, core analysis and other types of logging. The objective of these exploration surveys is to locate geothermal reservoirs.

As there are many types of geothermal resources, it is necessary to establish the exploration system which suits one of each type. In a broad way, geothermal heat itself and/or geologic structure are the keys to the exploration. A structural boring is done into the geothermal reservoir recognized by compiling every result of the surveys and all the cores are preserved for the analysis of reservoir characteristics. After the rough surveys, detailed surveys follow drilling at least three exploratory wells (six wells in a practical manner in Japan.) The reservoir size, reserves, fracture distributions and production ability are evaluated to provide data for the next development subsystem.

(2) Development and production subsystem

A reservoir model is composed as a function of outer valuables such as the reservoir delimitations assumed by the above submodel, the location, number and depth of exploratory wells, information obtained from them, and geological, topographical and environmental factors. Then the optimum project scheme is set up and carried out. In the development stage, the data from drilling of the production wells and various well tests performed at the same time are put together for the necessary calibration of the model.

It proceeds to the production stage and providing data for the next production and transportation subsystem. In the production stage in accordance with the various accumulated data, the optimum condition of the project is 'obtained by defining the uncertain factors involved with the heat source and the discharge mechanics. Therefore the production system from the reservoir to the well head is independently designed to be made optimum at each time step. The principles of the model of the development and production system are as follows.

1) Objective process

When the project is concluded to be feasible and the development starts, the subsystem deals with software which covers to the start of operation, field works such as drilling of wells and the progress to the well head of a production well in the operation stage. The system is devided into following steps.

1 decision whether the site be developed or not
2 reservoir investigation
3 development scheme
4 from the reservoir to the bottom hole of development and production wells
5 from the bottom hole to the well head
6 from the well head to the bottom of an injection well
7 from the bottom hole of injection well to the reinjected reservoir

2) The function of the system

1 As a part of the total system, it can simulate various characteristics of above process (costs, efficiency etc.)

2 It can simulate the process independently when provided with data from other subsystems. Bases for the evaluation of the optimization are;

A) Before and during the stage of development

i) minimization of drilling, operation and construction costs

ii) maximization of efficiency (recoverability, lifespan) from a macroscopic view point (volmetric method, material balance method)

iii) fracturing according to circumstances

iv) steam quality etc.

B) In the stage of production

i) minimization of production or discharge decline (operation cost)

ii) maximization of efficiency from a microscopic view point (simulation of the reservoir) for example; minimization of pressure loss at given production rate and enthalpy

iii) others

(3) Transportation and multipurpose utilization subsystem

The produced geothermal fluid from the production well is sent to a separator where it is separated into vapor, liquid and solid. The vapor. is transported to a power plant, while the portion of the hot water is delivered through pipes to be utilized multipurposely, the rest being reinjected through injection wells. The subsystem involves the fluid transportation from the site to the power plant and to other utilizing facilities, various problems of fluid treatment and the systematization of the large scale, multipurpose utilization of the hot water at discrete temperature.

(4) Power plant subsystem

Though there are different kinds and types of geothermal reservoirs which may well vary widely, the minimization of unit cost of electricity or sometimes even the maximization of output assuming economy of second importance, is required without exception. The power plant subsystem is needed to draw the optimum project of power generation which satisfies the given conditions. There are broadly two types of power generating method one uses natural geothermal steam, the other runs the steam separated from hot water.

i) produced steam is sent directly to a turbine.

ii) the steam separated from hot water through a separator is sent to a turbine.

iii) flashed steam under the reduced pressure is used to run a turbine.

Binary cycle plant and total flow plant are now under development in Japan.

(5) Environmental preservation subsystem

The subsystem provides various countermeasures against the environmental impact which has been predicted in advance and which occurs during the period of development of the geothermal field. Tt should he used in accordance with every other subsystem. Climate, atmosphere, waters, noises, vibrations, ground animals and plants and landscape scenery are to be carefully nonitored.

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