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Interference test simulation of Geothermal two phase field using PTA software and TOUGH2

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Abstract. Interference test simulation is conducted to find out the relationship between active well and observation well in a reservoir system through Bottom hole pressure (BHP) Transient analysis of interference test pressure data was performed using PTA software, while interference test simulation was performed using TOUGH2. The main parameters that become input data for transient pressure analysis are Bottom Hole Pressure and flow rate during interference test. Transient pressure analysis is used to determine the condition of wells, reservoir characteristic and the reservoir boundary conditions during the interference test. The research method are calculation of Bottom Hole Pressure with hydrostatic method, transient pressure analysis and reservoir simulation. The results are an interference indication between the WWA-4 and WWA-6 wells in the simulation model of interference test with the transmissivity value 4.7E3 Darcy-meter and storativity value 23.4 m at aquifer thickness value 100 m.

1. Introduction

Interference test simulation for two phase liquid dominated field are conducted to analyse the connectivity between active and observation well in the same area. Information about the reservoir thickness required to complete the reservoir volume definition according to [2]. WWA-4 is an active well with a maximum temperature 266 ° C and pressure 69 bara. WWA-4 is located in two phase liquid dominated reservoir. Interference test was conducted at WWA-4 and another observation well to determine the rock characteristic between wells.

The transmissivity needed to understand the well spaces and the number of wells required during the production period and to determine the thickness of the reservoir volume. The change of mass flow rate and pressure on wellhead after fluid is produced with different flow rate conditions which can be observed in interference test. The transient pressure response at each well can only be analyzed by the type curve matching method. The purpose is to get the same observation pressure response profile in model with interference test result in the field.

2. Methodology and Data

2.1 Methodology

The purpose of interference test simulation are into modeling the pressure response and the connectivity between wells and finding the basic rock properties between active and observation well for several radius investigation. Transient analysis conducted by selecting the WHP from interference between WWA 4 as an active well, and observation well (WWA-2, WWA-6, WWF- 2, WWT-2, WWT-4, WWA-5 and WWD-1). All WHP data provide with the date and time that giving clues to the present of tidal effect and production and shut-in process of the well. Plotting data is conducted between active well and observation time at the same pressure scale. Flow chart of the Methodology shown in Figure 1.

Figure 1. Flow chart of interference test methodology
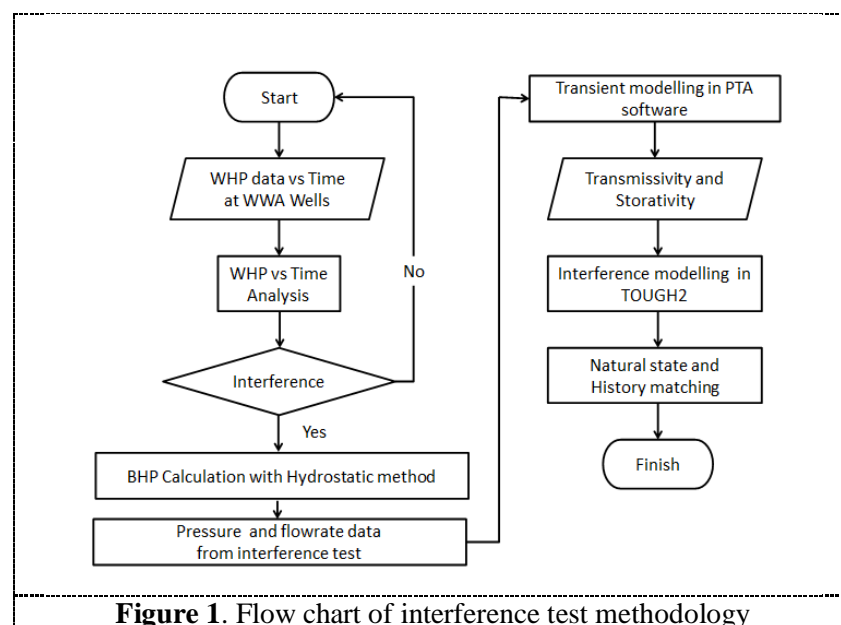
After conducting interference test by discharging WWA-4, then collecting the WHP data from observation wells. The WHP responded to the rock properties near the well and shows initial pressure and temperature distribution from the reservoir. Monitoring WHP (wellhead pressure) is conducted to identify and to predict homogeneous permeability. Figure 2 gives information about WHP between WWA-4 and WWA-6. The trend shown an interference between WWA-4 and WWA-6 with no tidal effect. Drawdown occurs when WHP is set to 15 barg, then setting in fully open condition. After the fully open condition build up occur in WWA-4. Observation well has shown the similar trend with the active well.
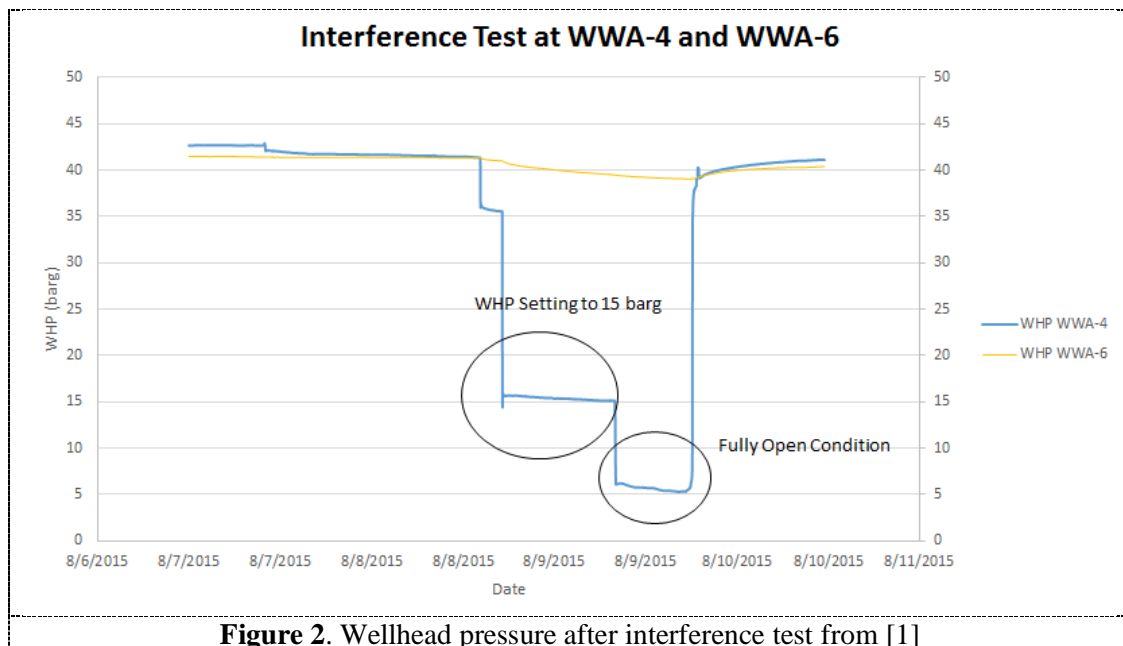
Figure 2. Wellhead pressure after interference test from [1]

In the drawdown step of producing wells of fluids from wells with different flow rates (for different WHP values) the observation well curves decrease, although not on the same scale as the pressure drop from the active well curve of the well . After the well closed (shut-in) there is an increase trend from WHP of the active well. The pressure of the well have the same condition with reservoir pressure. Interference observation wells will show an increase in WHP value in the comparison graph between active well and observation well. At the same time (during shut-in) the observation well pressure and active well press once again plotting in the same pressure scale.

Hydrostatic pressure used to converting WHP to the configuration of perforated liner data. WHP data processing from the field during the interference test is to convert the pressure into BHP pressure (Bottom Hole pressure). The baseline data of the observation wells that input into the PTA software must be a well Bottom hole pressure (BHP). Therefore the pressure drop of the well is calculated by the hydrostatic pressure method. In a two-phase liquid dominated reservoir, the reservoir pressure profile of the brine layer can be adapted to hydrostatic conditions of wellhead pressure.

Well Production data gives a clue to rock characteristic near the active and observation well. The interference test performed by measuring the wellhead pressure before the active well is produced, then the active well pressure setting on the wellhead pressure of 15 barg, after the well is opened with fully open condition (Figure 2). Based on the principle of interference test a well has an interference with another well if its pressure response profile to the well produced has a similar trend of pressure. Changes in pressure to distances are affected by rock properties. Wellhead pressure data from the observation well are considered to represent the reservoir state. Each observation well shown a different pressure response. Bottom hole pressure estimates by hydrostatic pressure method. The next step is to validate the transmissivity data of the simulated interference test with the thickness and transmissivity values that have been obtained using transient pressure analysis. The failure in reading pressure field data affected by tidal effects. The tidal effect causes difficulties in identifying the interference between wells. The pressure data affected by the tidal effect can't be used for PTA software (Figure 3).
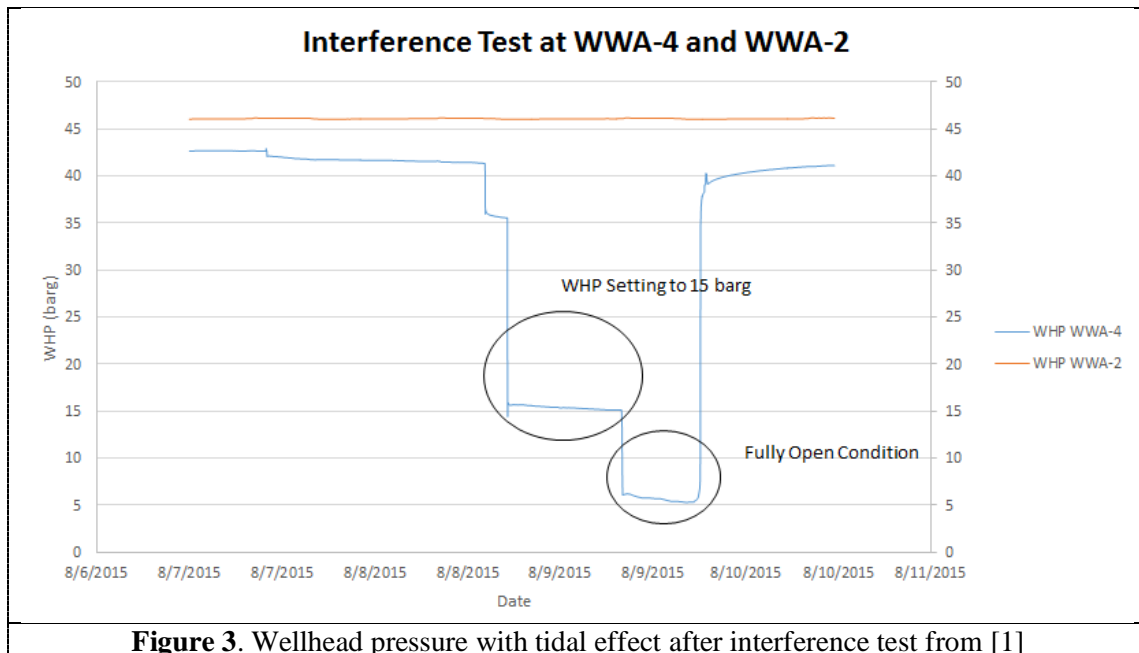
Figure 3. Wellhead pressure with tidal effect after interference test from [1]

This graphs shows there is a tidal effect shown in Figure 3. WWA-2 doesn't show a response to WWA-4 when the WHP is set to 15 barg and fully open condition. The graph shown there is a range between WHP of WWA-4 and WWA-2.

2.1.1 PTA Analysis Method.

PTA software (Figure 4) used to analyze well and reservoir conditions. The well BHP give information about the presence of skin, pressure drop caused by skin and wellbore storage in the well. the reservoir characteristic can be analyzed by transmissivity between wells and fluid potential stored in the reservoir (storativity). The input data for PTA software including payzone thickness (h), well radius (r), wellbore distance (d), flow rate (active flow rate), well observation pressure to time and coordinates of active well location and observation wells. , the interference test data then extracted dP to obtain the dimensionless pressure and time dimensionless parameters of the interference test data entered into the PTA software.

Dimensionless pressure, type curve matching. adjust the well type, reservoir and outer boundary of the reservoir to get the value of transmisivity and storativity. In PTA software the flow rate data is calculated by the superposition method to obtain ΔPskin value. Log log data plot readings from the transient pressure analysis were performed to analyze flow patterns occurring in wells after production and shut-in using log log data plot and semilog straight line. The log-log data plot is obtained from a field dimensionless pressure data calculated using the type curve matching method. If data didn't match, then change the time to flow rate. Having obtained matching data, the result data of PTA analysis can be used to validate the interference test simulation model in TOUGH2 (Figure 7).

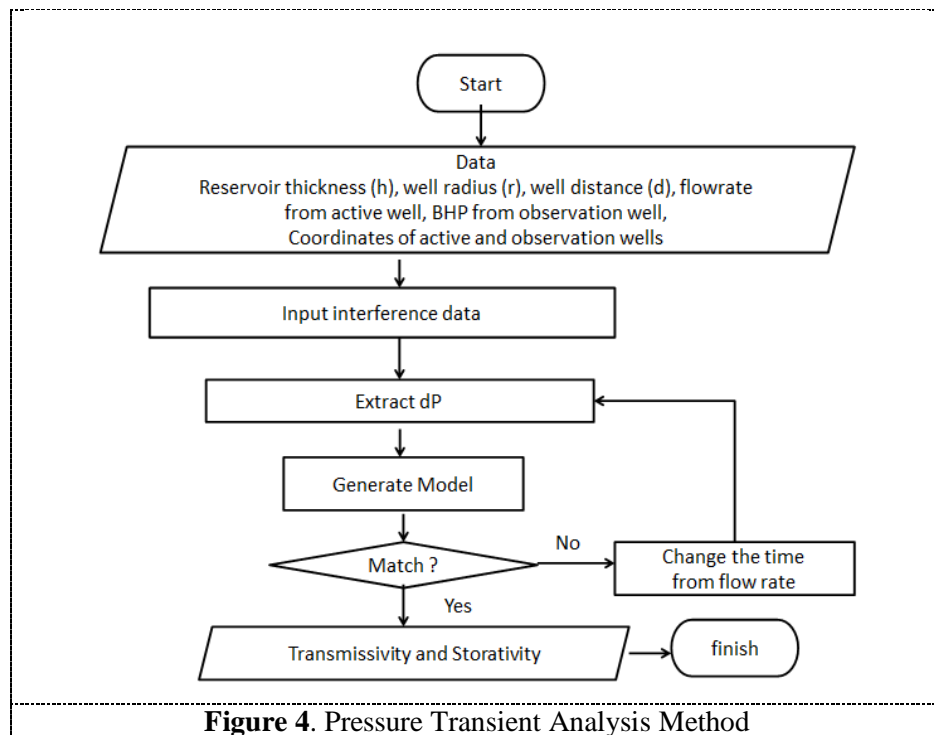**Figure 4**. Pressure Transient Analysis Method

Figure 4 illustrates PTA Analysis method, collecting data includes the reservoir thickness, well radius, flowrate from active well, BHP from the observation well and also the coordinates of active and observation well. After collecting all data, we input BHP data from interference.

2.1.2 Interference test Simulation Method In TOUGH2.

The modeling of interference test simulation using TOUGH2 (Figure 4) is conducted by natural state and history matching. Natural state required to obtain the conditions of pressure and temperature distribution (example: Figure 5) in the model at the initial conditions of the two phase liquid dominated field to obtained the feed zone, the maximum temperature and maximum pressure of the wells. The history matching required to obtain a pressure gradient condition on the model after production in the field. Vertical permeability is one-tenth of the horizontal permeability [4].

The grid relates the rock properties near the well and discharging from active well can cause pressure disturbance with . Each grid around the well contains adapted rock parameters based on the data on the interference test water two phase simulation from the PTA software.
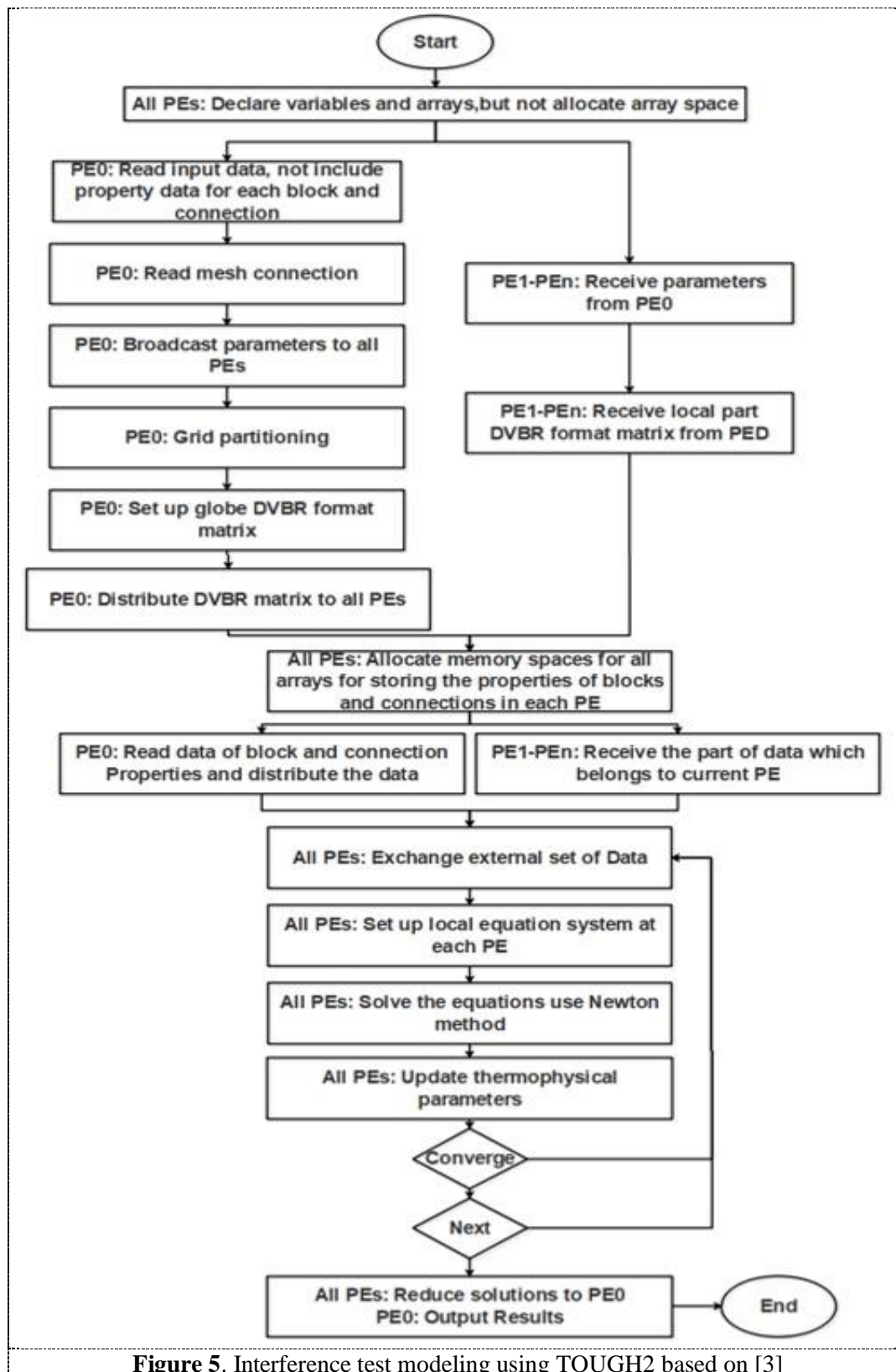
Figure 5. Interference test modeling using TOUGH2 based on [3]

2.2 Data

The input data for transient analysis are Wellhead well pressure data from active wells and several observation wells from [1]. These data were used to obtain the BHP pressure from the observation well. The another data are pressure and temperature profile from active and observation wells [1]. The another data for interference simulation modeling are Wayang windu conceptual model [5], the configuration of perforated liner [7], active and observation wells coordinates [1] and flowrate of active well [6].

3. Result and Discussion

3.1 Result

WWA-4 wells and WWA-6 wells have interference shown in table 1. This is evident from the WWA-6 observation well pressure profile following the pressure trend of the active well. Before the active well is produced the well observation pressure profile approaches the active well profile. After the active well is produced, response from interference test is an effect of superposition pressure from the production of the WWA-4 well flow rate to the WWA-6 well so that the well pressure drop becomes 2 barg. For a given data, there is a tidal effect between WWA-4 and WWA-2. For example, the WHP of WWA-2 has a different trend with WWA-4 (Figure 8).

Table 1. Interference Test Results

Active Well	Observation Wells	Analysis Results
	WWA-2	Tidal effect
	WWA-6	Interference
	WWF-2	Tidal effect
WWA-4	WWT-2	Tidal effect
	WWT-4	Tidal effect
	WWA-5	Tidal effect
	WWD-1	Tidal effect

Analysis of Line source profile from WWA 6 well shows the effect of wellbore storage and skin on $\Delta t = 1$- 2 hr (Figure 6). Furthermore, reservoir fluid flow can be seen at $\Delta t = 3$ - 10 hr. The figure 3 shows the dimensionless estimates The dimensionless pressure data fit the well with wellbore storage and skin in homogeneous reservoir. The transient pressure analysis results in the interference test data shows the outer boundary of the infinite reservoir.
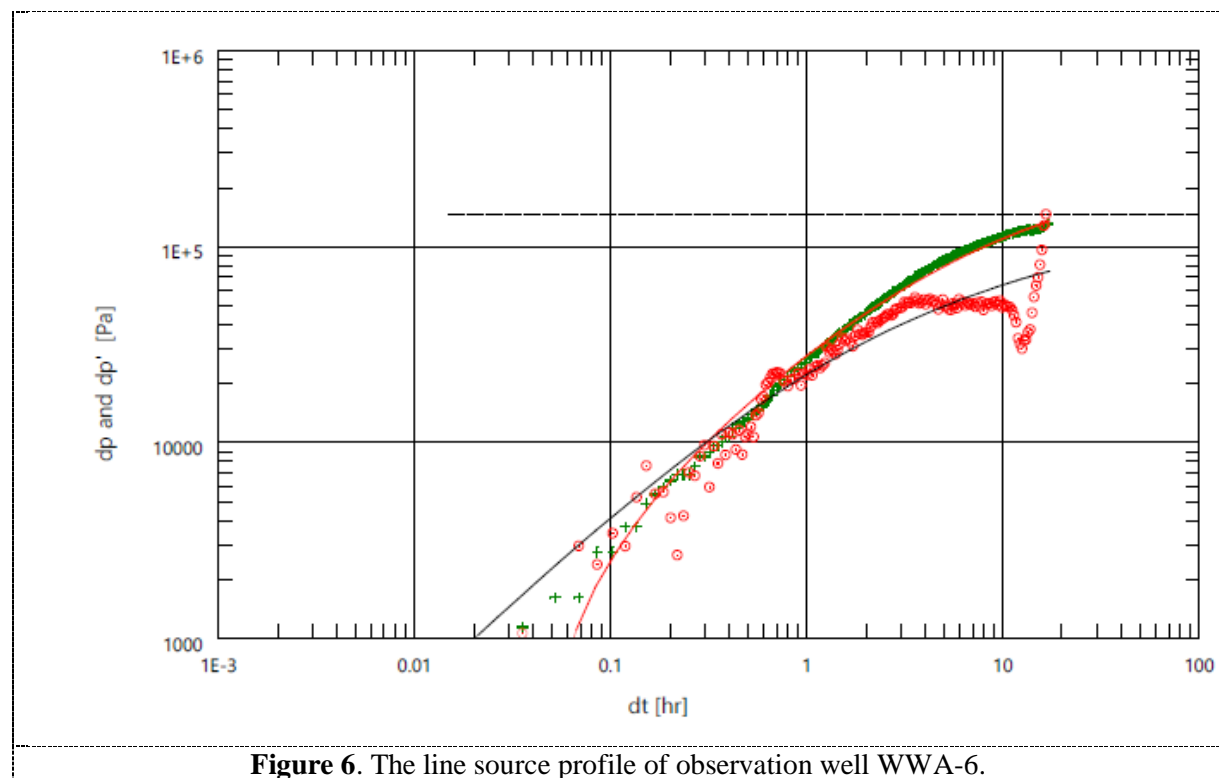
Figure 6. The line source profile of observation well WWA-6.

Interference data of WWA-6 fit the line source with Pmatch= 3.46E-6 Pa, Tmatch= 33,9hr, P@dt=0 4,9E+6 Pa for initial pressure 5.13E+6Pa and rate change 8.6m^3/sec. The transient model indicates wellbore storage at 0.503m^3/Pa and skin -11.1. Using the configuration of perforated liner. The well modeled with type storage and skin and reservoir modeled homogeneus with type boundary infinite. The data fit with Rinv 9510 m, This indicates that with the flow rate with time (for 4 days), the transient pressure spreads along a radius of 6.6E9 m3. The permeability-thickness value (4.7E3 Darcy-meter) and porosity-thickness (23.4 m). The observation well condition was analyzed based on semilog straight-line method.

Table 2. Rock Characteristic of WWA-6

Parameters	Amount	Criteria
k.h (permeability thickness)	4.73E-9 m3	Good transmissivity
k (permeability)	4.12E-11m2	Good permeability
Phi (porosity)	0.204	Tight porosity
Phi.h (Porosity thickness)	23.4m	Tight storativity

The parameter WWA-6 of two phase geothermal field fit with two phase water – oil type (Table 2). The output parameter from transient modelling from water-oil type are used for validate natural state modelling in TOUGH2. Material LIQ1, liq2 and BASE fit with PTA results.interference on WWA wellpad show good permeability and tight porosity.
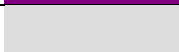
Table 3. Material Type of TOUGH2
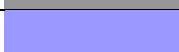
Material	Color	Density	Porosity	X permeability	Y Permeability	Z Permeability	Wet Heat Conductivity	Specific Heat
Unit		kg/m^3	-	Md	Md	Md	W/m^{o}C	J/kg^{o}C
ATM		2600	1	4E-15	4E-15	1E-16	2	1000
GWR		2600	2E-3	4E-7	4E-7	1E-8	2	1000
CAP 2		2600	5E-2	1E-4	1E-4	1E-5	2	1000
BD 2		2600	0.1	1E-7	1E-7	1E-8	2	1000
LIQ 1		2600	0.1	1E2	1E2	10	2	1000
Liq2		2600	0.1	1E3	1E3	1E2	2	1000
BASE		2600	0.2	1E2	4E2	10	3	1000

Table 3 gives the properties detail of model material. The transient pressure in the interference test simulation occurs by producing wells at different flow rates. Production of active wells causing pressure disturbances to observation wells. The resulting flow rate at observation well is equal to the amount produced in the field when the interference test is conducted. As long as the active wells was produced, the observation well is in shut-in condition. The purpose is to observe the amount of pressure disturbance received by the observation wells after the production of the active well.

In TOUGH2, the pressure and temperature of each grid block are affected by the permeability value (Table 3). The greater the permeability value in the grid block the more sensitive the changes in the value of pressure and temperature. Interference test simulation representative (Figure 4) is used to find out the grid block with high sensitivity to pressure and temperature caused by high fluid compressibility, transmissivity and storativity in an area of the grid block.
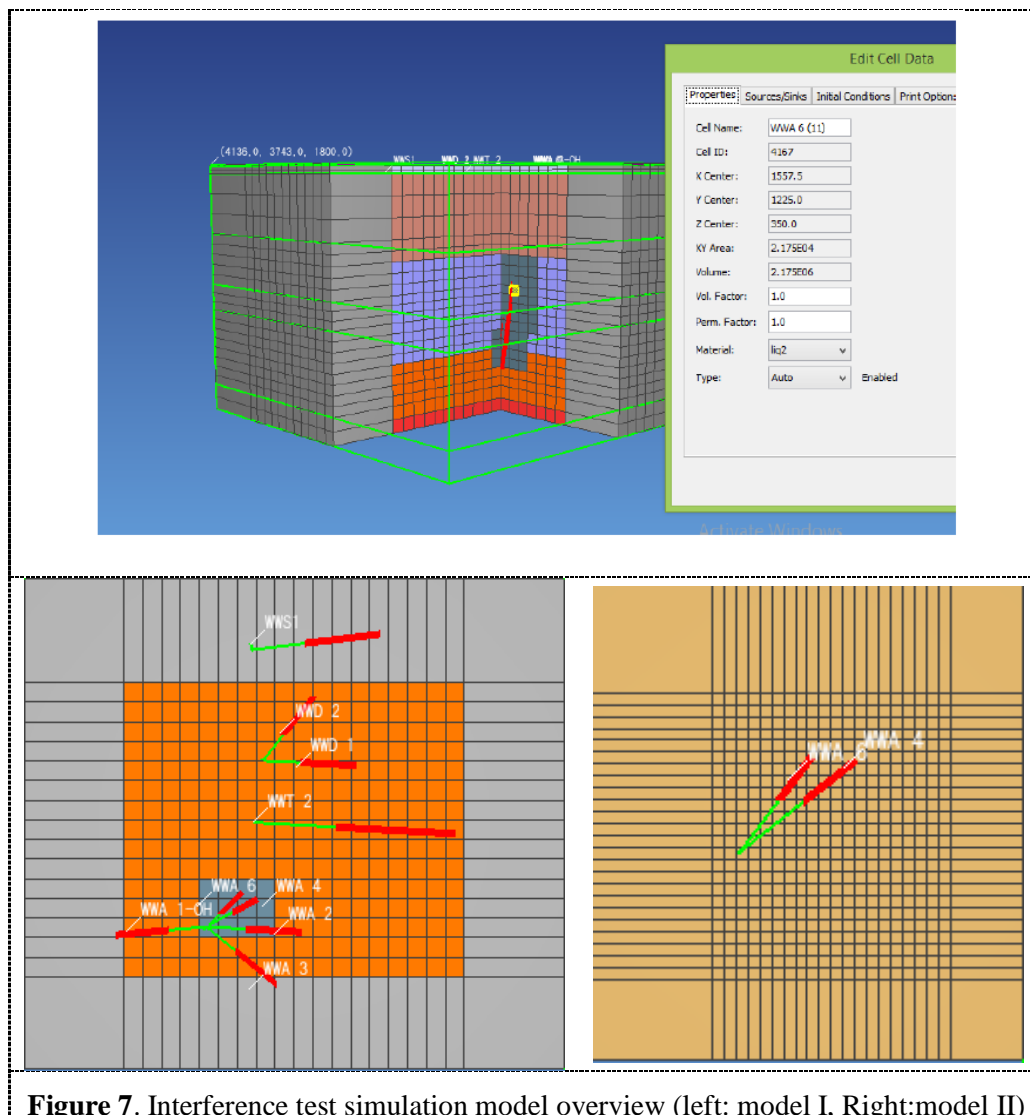
Figure 7. Interference test simulation model overview (left: model I, Right:model II)

3.2 Discussion

The sensitivity of the interference test model was conducted on two synthetic models shown in Table 4, namely model I and model II. Model I represented the simulation of interference test with grid 17 x 20 system, while model II represented simulation of interference test with grid system 26 x 22. Natural state condition of model I based on pressure and temperature of 5 wells, while natural state condition II based on pressure and temperature of 2 wells. Comparison to model II conducted with variation in the number of grid.

The sensitivity of the model helps to determine pressure near the bottom pressure condition of the well as the perforated liner depth. The sensitivity results are the difference of well pressure between model I and model II at perforated liner depth. The simulation results show that the initial reservoir pressure of model I is smaller than the initial pressure of reservoir model II. This difference affected by the temperature of well of model I that more varied than model II. Respon on model II with same properties to model I is the boundary of model I has a higher temperature.

Table 4. Sensitivity of Interference Test Simulation Model

	Model I	Model II
Grid System	17x20	26x22
Active Well	8160	14872
Number of Wells	5	2
	(WWA-4,WWA-6,WWA-3, WWA-2,WWA-1OH)	(WWA-4,WWA-6)
Completion Thickness	115	115
Pi (bara)	51	57
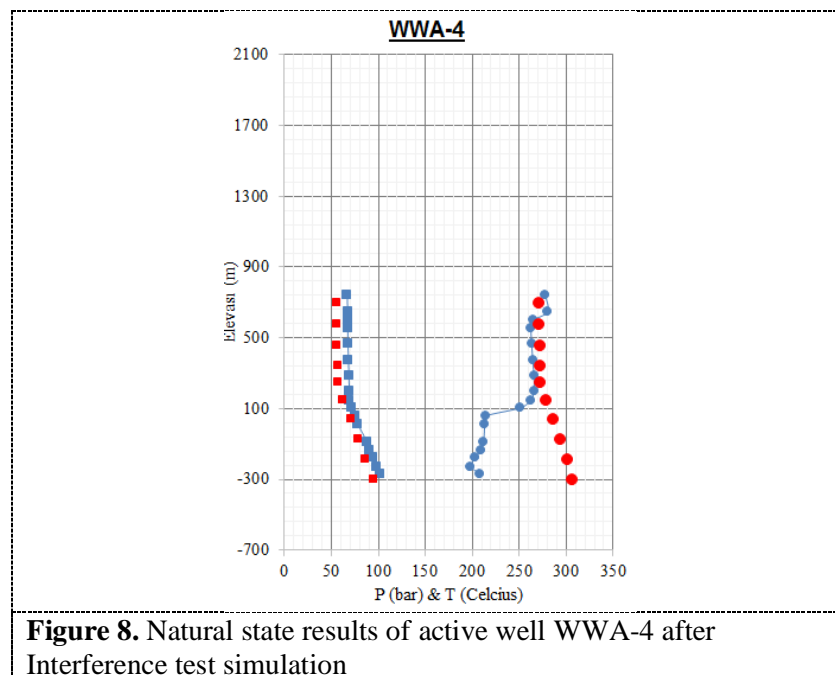
Figure 8. Natural state results of active well WWA-4 after Interference test simulation

4. Conclusion

Transient Modeling has conducted for two-phase liquid dominated reservoir. Interference test simulation was conducted to find the reservoir thickness and connectivity between two or more than two wells. In two phase liquid dominated reservoir, interference has matched by Pressure and temperature curve. Parameters in PTA software with oil-water phase can be used for two phase liquid dominated geothermal reservoir. The measurement of permeability thickness (transmissivity) and porosity thickness (storativity) based on the WHP data from interference test that can give information connectivity between two wells or more and information about tidal effect.

There is a transmissivity estimates to a 115 m thick aquifer with a permeability of 5E3 md (the permeability distribution is estimated to be 1E3 md (x), 1E3 md (y) and 1E2 md (z)). Interference results from PTA software indicates homogeneous reservoir type with permeability – thickness (4.7E3 Darcy-meter) and porosity- thickness (23.4). Data from interference test fit the line source profile for water – oil phase and can validate the material and rock properties for natural state modeling in TOUGH2. Average production enthalpy from active well is1367,87 KJ/Kg. The interference test simulation results indicates there is boiling zone at permeable region with tight porosity.

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