Oil & Natural Gas Technology

DOE Award No.: DE-FE0024271

Quarterly Research Performance

Progress Report (Period Ending September 30, 2017)

Fracture Diagnostics Using Low Frequency Electromagnetic Induction and Electrically Conductive Proppants

Project Period (October 1, 2014 – September 30, 2018)

Submitted by:
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Office of Fossil Energy

2. ACCOMPLISHMENTS:

Work during this quarter was focused on the inversion of the electrical data gathered by the tool. This is essential to interpret the measurements and obtain the fracture geometry.

- A sequential search inversion algorithm was developed for the induction tool that accounts for the measurements of electric field made in all three directions for the short, medium and long spacing detectors.
- It was demonstrated that for simple fracture geometries and for single fractures it is possible to invert the measured data to obtain the fracture geometry within a relatively small number of iterations (10 to 100 forward runs).
- An inversion algorithm was also written for the resistivity tool (for cased holes). This was essential to show that it would be possible to invert the data to obtain fracture geometry with no azimuthal resolution (the tool does not resolve the electric field in 3 directions).
- Results from the inversion clearly show that for simple fracture geometries (planar fractures) it is possible to obtain the fracture geometry from the measurements made at different casing locations on either side of the transmitting node (pair of casing sections).
- In the coming quarter the inversion model will be used to invert data for cases that involves multiple fractures. This is a much more realistic scenario. We expect to learn how long such inversions will take and how good the inverted results are. We expect some degree of non-uniqueness in the results. This will need to be constrained by making physically reasonable assumptions/models for the fractures.
- The induction tool that had been buried at the shallow subsurface test site was recovered and brought back the E-Spectrum facility. No further field tests are planned.
- Regular weekly meetings were held with the E-Spectrum team to better coordinate our efforts under this contract and to organize the SBIR Phase 2 work.

3. PRODUCTS:

None.

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:

Name:	Yaniv Brick
Project Role:	Postdoctoral Fellow
Nearest person month worked:	3
Contribution to Project:	Need Info
Funding Support:	ICES Postdoctoral Fellowship
Collaborated with individual in foreign country:	No
Country (ies) of foreign collaborator:	No
Travelled to foreign country:	No
If traveled to foreign country (ies), duration of stay:	0 months

Partner Organizations

Organization Name: E-Spectrum Technologies.
Location of Organization: San Antonio, Texas
Partner's contribution to the project:

- Collaborative research (e.g., partner's staff work with project staff on the project).
- Design and building of tool.

More detail on partner and contribution:

- Several joint meetings were held with E-Spectrum to better define the tool requirements and the results needed from the simulations to help with the tool design.

5. IMPACT:

The proposed technology has the following key advantages, which is not presently offered by any technology in the market:

a. It can be executed from a single wellbore.

b. It is a direct far field measurement.

c. This tool can be run in hole after hydraulic fracturing. If the need arises, it can be used at any time during the well's life cycle providing a time lapse analysis of fracture growth or closure.

d. Since it obtains tri-directional signals, these tensors can be resolved to obtain a simulated volume map, which can be correlated directly to the productivity of a given well.

e. This is the only technology that can obtain propped fracture length, which governs productivity of a given well. Also it can be used to detect proppant banking or anisotropy in hydraulic fracture growth.

We anticipate that the technology will have a very significant impact on fracture diagnostics as it is cheap, repeatable, and fairly simple to run. In addition to the key critical advantages mentioned above the proposed technology can also offer the following benefits which are in line with DOE's ongoing efforts:

a. Additional recovery: This tool can improve our understanding of true stimulated rock volume, since it tracks propped volume of hydraulic fractures and not shear slip events during a fracturing job. Therefore, using this technology, we can model the reservoir better and find effective re-fracturing candidates. Also a true stimulated rock volume map can help us design better simulations for subsequent wells.

b. Reduced costs: This tool can be operated at any time during the well's life cycle and not necessarily during the hydraulic fracturing job (as is the case with microseismic monitoring). Therefore, it will be reduce the equipment load during a fracturing job, thereby reducing the environmental footprint. Since this technology, being a single wellbore application, doesn't require a monitoring well, it can be potentially deployed in any hydraulically fractured well with or without a rig (can be deployed with a MAST truck too). Due to the simplicity of deployment and ease of operation, we anticipate a much reduced cost as compared to microseismic monitoring while providing more reliable results.

c. Environmental benefits: This technology basically tracks the location of conductive proppant using the proposed electromagnetic logging tool. Therefore it can used to track if the fractures are hydraulically connected to natural aquifers. This tool can be run alongside Cement Bond Logs, in fractured reservoirs to ensure hydraulic isolation of oil and gas producing zones. Also the inverted product of this data can be combined with other geophysical data (2D and 3D seismic and/or CSEM data) to find connection with natural fractures.

6. CHANGES/PROBLEMS:

None.

7. SPECIAL REPORTING REQUIREMENTS:

None.

8. BUDGETARY INFORMATION:

EXHIBIT 1 – MILESTONE STATUS REPORT

Milestone Title/Description	Planned Completion Date	Actual Completion Date	Verification Method	Comments (Progress toward achieving milestone, explanation of deviation from plan etc.)
Task 1. Project Management & Planning				
Milestones				
Completed project management & planning	11/1/14		PMP document	
Task 2. Development of forward model using proposed tool and different fracture geometires				
Milestones				
model of fracture in well completed	6/30/15			
forward model to observe signal	9/30/15			
important operational parameters	3/31/16			
Publication #1			Paper publication submitted	
Task 3. Lab testing of available proppants in the market for electrical and material properties				
Milestones				
identify the best proppants for their electrical conductivity and strength	3/31/16		Lab test report provided for review	
Task 4. Construction of low frequency electromagnetic tool				
Milestones				
low frequency electromagnetic tool built and lab tested according to well specifications	12/31/16			
Task 5. field testing of tool				
Milestones				
Built tool deployed in well	2/28/17		Tool is deployed on well site	
publication #2			Paper publication submitted	
Task 6. Inverting the obtained field data for stimulated rock volume (SRV) map				
Milestones				
invert the tool signal to obtain stimulated rock volume (SRV) map				
Publication #3	10/31/17		Paper publication submitted	
illustrate the new technology as a fracture diagnostic tool				
Final Report	12/31/17		Final report	

EXHIBIT 2- COST PLAN

	Budget Period 1								Budget Period 2								Budget Period 3							
	Q1		Q2		Q3		Q4		Q1		Q2		Q3		Q4		Q1		Q2		Q3		Q4	
Baseline Reporting Quarter	10/1/14 - 12/31/14		1/1/15 - 3/31/15		4/1/15 - 6/31/15		7/1/15 - 9/30/15		10/1/15 - 12/31/15		1/1/16 - 3/31/16		4/1/16 - 6/31/16		7/1/16 - 9/30/16		10/1/16 - 12/31/16		1/1/17 - 3/31/17		4/1/17 - 6/31/17		7/1/17 - 9/30/17	
	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total	Q1	Cumulative Total	Q2	Cumulative Total	Q3	Cumulative Total	Q4	Cumulative Total
Baseline Cost Plan																								
Federal Share	$ 133,921	$ 133,921	$ 133,922	$ 267,843	$ 133,921	$ 401,764	$ 133,921	$ 535,685	$ 133,922	$ 669,607	$ 133,922	$ 803,529	$ 133,922	$ 937,451	$ 133,921	$ 1,071,372	$ 133,921	$ 1,205,293	$ 133,922	$ 1,339,215	$ 133,922	$ 1,473,137	$ 133,921	$ 1,607,058
Non-Federal Share	$ 48,602	$ 48,602	$ 48,603	$ 97,205	$ 48,602	$ 145,807	$ 48,602	$ 194,409	$ 48,602	$ 243,011	$ 48,603	$ 291,614	$ 48,602	$ 340,216	$ 48,602	$ 388,818	$ 48,602	$ 437,420	$ 48,603	$ 486,023	$ 48,602	$ 534,625	$ 48,603	$ 583,228
Total Planned	$ 182,523	$ 182,523	$ 182,525	$ 365,048	$ 182,523	$ 547,571	$ 182,523	$ 730,094	$ 182,524	$ 912,618	$ 182,525	$ 1,095,143	$ 182,524	$ 1,277,667	$ 182,523	$ 1,460,190	$ 182,523	$ 1,642,713	$ 182,525	$ 1,825,238	$ 182,524	$ 2,007,762	$ 182,524	$ 2,190,286
Actual Incurred Cost																								
Federal Share	$ 30,972	$ 30,972	$ 26,985	$ 57,958	$ 99,655	$ 157,613	$ 148,601	$ 306,214	$ 113,085	$ 419,299	$ 56,524	$ 475,823	$ 55,289	$ 531,112	$ 85,464	$ 616,576	$ -	$ 616,576	$ -	$ 616,576	$ -	$ 616,576	$ -	$ 616,576
Non-Federal Share	$ 75,222	$ 75,222	$ 64,495	$ 139,717	$ -	$ 139,717	$ -	$ 139,717	$ 26,510	$ 166,227	$ 26,510	$ 192,737	$ 78,190	$ 270,928	$ 34,669	$ 305,596	$ -	$ 305,596	$ -	$ 305,596	$ -	$ 305,596	$ -	$ 305,596
Total Incurred Costs	$ 106,194	$ 106,194	$ 91,480	$ 197,675	$ 99,655	$ 297,330	$ 148,601	$ 445,931	$ 139,595	$ 585,526	$ 83,034	$ 668,560	$ 133,480	$ 802,040	$ 120,132	$ 922,172	$ -	$ 922,172	$ -	$ 922,172	$ -	$ 922,172	$ -	$ 922,172
Variance																								
Federal Share	$ 102,949	$ 102,949	$ 106,937	$ 209,885	$ 34,266	$ 244,151	$ -14,680	$ 229,471	$ 20,837	$ 250,308	$ 77,398	$ 327,706	$ 78,633	$ 406,339	$ 48,457	$ 454,796	$ 133,921	$ 588,717	$ 133,922	$ 722,639	$ 133,922	$ 856,561	$ 133,921	$ 990,482
Non-Federal Share	$ -26,620	$ -26,620	$ -15,892	$ -42,512	$ 48,602	$ 6,090	$ 48,602	$ 54,692	$ 22,092	$ 76,784	$ 22,093	$ 98,877	$ -29,588	$ 69,288	$ 13,933	$ 83,222	$ 48,602	$ 131,824	$ 48,603	$ 180,427	$ 48,602	$ 229,029	$ 48,603	$ 277,632
Total Varience	$ 76,329	$ 76,329	$ 91,045	$ 167,373	$ 82,868	$ 250,241	$ 33,922	$ 284,163	$ 42,929	$ 327,092	$ 99,491	$ 426,583	$ 49,044	$ 475,627	$ 62,391	$ 538,018	$ 182,523	$ 720,541	$ 182,525	$ 903,066	$ 182,524	$ 1,085,590	$ 182,524	$ 1,268,114

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