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Surface Electromagnetic Prospecting System Sikar District, Rajasthan

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Abstract: ***To test the performance of the Rajasthan whole-surface electromagnetic prospecting (SEP) system, system integrations, instrument performances, and large-scale production viabilities in Narsingpur and Gumansingh dhani were measured via extensive field tests. Resultant electric fields, magnetic fields, apparent resistivities, impedance phases, and inversion profiles compared favorably with results of commercial equipment from other countries. The inversion results agreed well with the geologic information from boreholes. Field tests showed that the SEP system is stable, reliable, lightweight, and easy to operate, making it suitable and ready for real-field exploration. Geophysical techniques have played an important and indispensable role in delineating structures and conductive zones for uranium exploration several areas in North Delhi Fold Belt (NDFB).***

Keywords: ground electromagnetic instrument, electromagnetic sounding system, SEP, NDFB

1. Introduction

To investigate the internal structure of the Earth and to prospect for underground resources, the usage of electromagnetic methods and techniques has recently increased (Unsworth et al., 2005; He et al., 2008; Bastani et al., 2009; Constable, 2010; Grayver et al., 2014; Ichiki et al., 2015; Singh and Sharma, 2015; Tang et al., 2015; Rees et al., 2016). To gain reliable knowledge of underground electrical structures, field data must be collected via observational equipment that is dependable and suitable for subsequent processing. The application of proper electromagnetic sounding equipment is the basis for successful implementation of electromagnetic sounding methods

In the late 1980s, digital acquisition and processing systems were introduced to geophysical instruments, making electromagnetic equipment more functional than it had ever been. A number of multi-functional EM sounding instruments are currently available in markets, such as Canada's Phoenix V5, V6, and V8 (Nabighian and Macnae, 1991); the United States' Zonge GDP-12, 16, 32, and 32II (Zonge and Hughes, 1991); and Germany's Metronix GMS05, GMS06, and GMS07, etc (Roy et al., 1999; Korja et al., 2008; Patro and Egbert, 2011). Propelled by continuous development and upgrades, these instruments have dominated the markets; in addition, they have played a significant role in resource exploration, engineering surveying, detection of crustal structure, and other areas.

Although these instruments are advanced, they are also expensive. Moreover, the power of their transmitters is not sufficiently high for many applications, and the instruments are not convenient to operate owing to the weight of their receivers. To effectively apply this technology to deep electrical structure surveys and resource exploration, we have developed a whole-surface electromagnetic prospecting (SEP) system. This system is based on solutions to a number of technological problems such as the use of a softswitch, a two-stage AC−DC topology, a high- permeability magnetic core, and weak signal detection

A subsystem development for the SEP system has been completed, and laboratory tests are finished. Laboratory tests included impact resistance testing, electromagnetic compatibility testing, high- and low-temperature testing, and humidity testing.

The first stage of field testing optimized the subsystems used by SEP. To assure each subsystem meets the application requirements in the field, we conducted many small field tests in Sikar , Rajasthan, and other locations.

The second stage of field testing forms the core of this study, which includes field integration and production detection for the entire SEP system in two locations. This stage is the final link in the research and development of the SEP system; it is a critical step toward the practical application and the production of this set of equipment and procedures. This study presents the important results from field tests in Gumansigh Dhani and Narsingpur, and the performance of the high-power transmitter, EM field data, apparent resistivity, and inversion results is shown and analyzed.

2. Literary Reviews

Ray, S.K., 1990, The Albitite Line of Northern Rajasthan: a fossil intracontinental rift zone. Jour. Geol. Soc. Ind, v 36, pp 413-423.

Reid, A. B., Allsop, J. M., Granser, H., Millet, A. J. and Somerton, I. W., 1990, Magnetic interpretation in 3-D using Euler deconvolution. Geophysics, v. 55, pp 80-91.

SEP system

The magnetotelluric method, the audio-frequency magnetotelluric method, and the controlled-source audio-frequency magnetotelluric method can all be applied using the SEP system, which includes a controlled-source subsystem, distributed receivers, and magnetic sensors. The main SEP parameters are listed in Table 1, which also facilitates comparisons with the V8 and GDP32 systems by listing their comparable parameters. The most striking advantage that the SEP system has over these dominant commercial instruments is its 50-kW transmitter power, which can provide a stronger signal. The SEP is a multi-channel receiver.

Table 1: Parameters of SEP, V8, and GDP32

Equipment	Parameter	SEP	V8	GDP32
Transmitter	Power	50 kW	20 kW	30 kW
	Frequency	up to 10 kHz,	up to 9.6 kHz	up to 8 kHz
	Channel	continuous 12	6	8
	A/D	24 bit	24 bit	16 bit
Receiver	Dynamic range	130 dB	120 dB	190 dB
	Size (mm)	250 × 220 × 125	355 × 250 × 110	430 × 410 × 230
	Weight	4.6 kg	7 kg	16.6 kg
	Model	IMC-01	AMTC-30	ANT-6
	Bandwidth	0.1 Hz–10 kHz	0.1Hz–10kHz	0.1Hz–10kHz
MT coil	Sensitivity	100 mV/nT	100 mV/nT	250 mV/nT
	Size (cm)	length 81.3 diameter 6.2	length 82 diameter 6.0	length 91 diameter 4.8
	Weight	3.6 kg	3.0 kg	3.2 kg
	Model	IMC-02	MTC-80	ANT-4
	Bandwidth	10000 s–1000 Hz	20000 s-400 Hz	2000 s–1000 Hz
	Sensitivity	800 mV/nT	50 mV/nT	100 mV/nT
	Size (cm)	length 88 diameter 4.5 cm	length 98 diameter 6.0 cm	length 138 diameter 4.8 cm
	Weight	3.7 kg	4.8 kg	6.2 kg

The performance of the magnetic sensor has also reached a level comparable to these commercial instruments.

SEP field tests in Narsgingpur, Gumansingh Dhani

The first field tests were conducted in the north Delhi fold belt, Rajasthan. Atomic Mineral Directorate has conducted numerous geological and geophysical studies in this area, including seismic exploration and electromagnetic prospecting via the Exploration and MT methods; thus a strong baseline of information is readily available for comparison with the SEP field tests.

Design of survey lines and field work

Exploration data were collected using the SEP system and the Phoenix V8 system along four linear transects spaced 50 m apart, as indicated in Figure 1. Each survey line was 3.75 km long, and survey Line 2 crossed wells JK-1 and JK-2. The length of the transmitter dipole was 1.5 km, the distance between the transmitter and the receivers was approximately 13 km, and the distance between each sounding point was 20 m. The data acquisition method used in this study is shown in Figure 2. Data observation was divided into two stages: first, the V8 transmitter was used to generate an EM signal, while the SEP receivers and the V8 receiver were used to collect data and second, the SEP transmitter was used while all receivers continued to collect data.

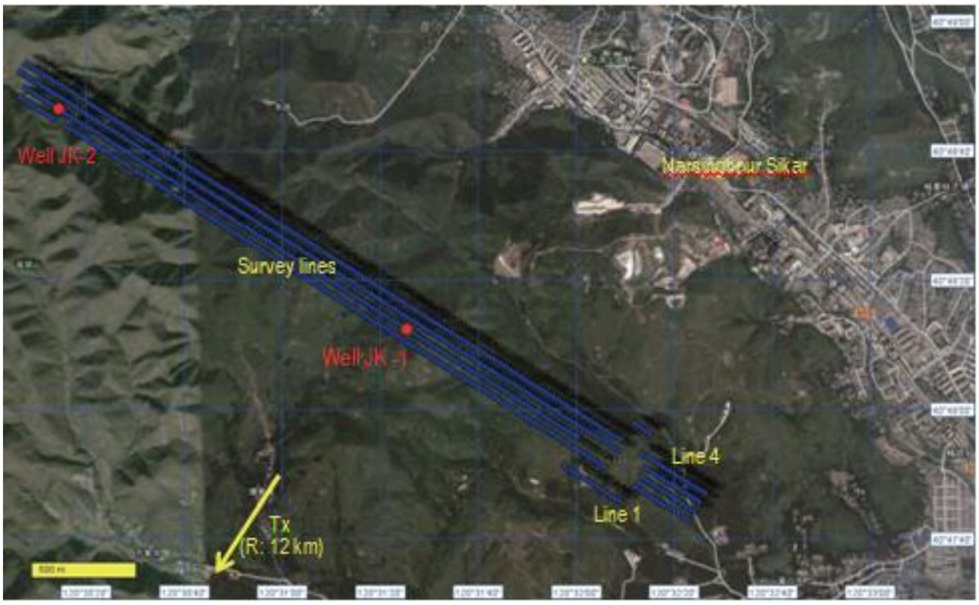

Figure 1: Exploration survey lines in the Sikar District area

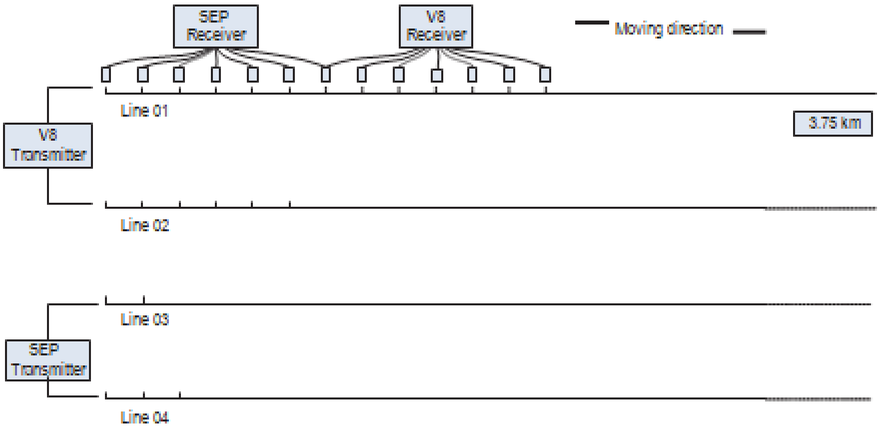

Figure 2: Illustration of data acquisition method for Exploration method

Field test results

First, performance comparisons between the SEP transmitter and the V8 transmitter were performed. Figure 3 shows a comparison between the SEP transmitter output waveform and V8 transmitter output waveform at 512 Hz. The results were similar to each other; however, the V8 transmitter waveform was slightly more stable than the SEP transmitter waveform, indicating that the performance of the SEP transmitter was worse than the V8 transmitter.

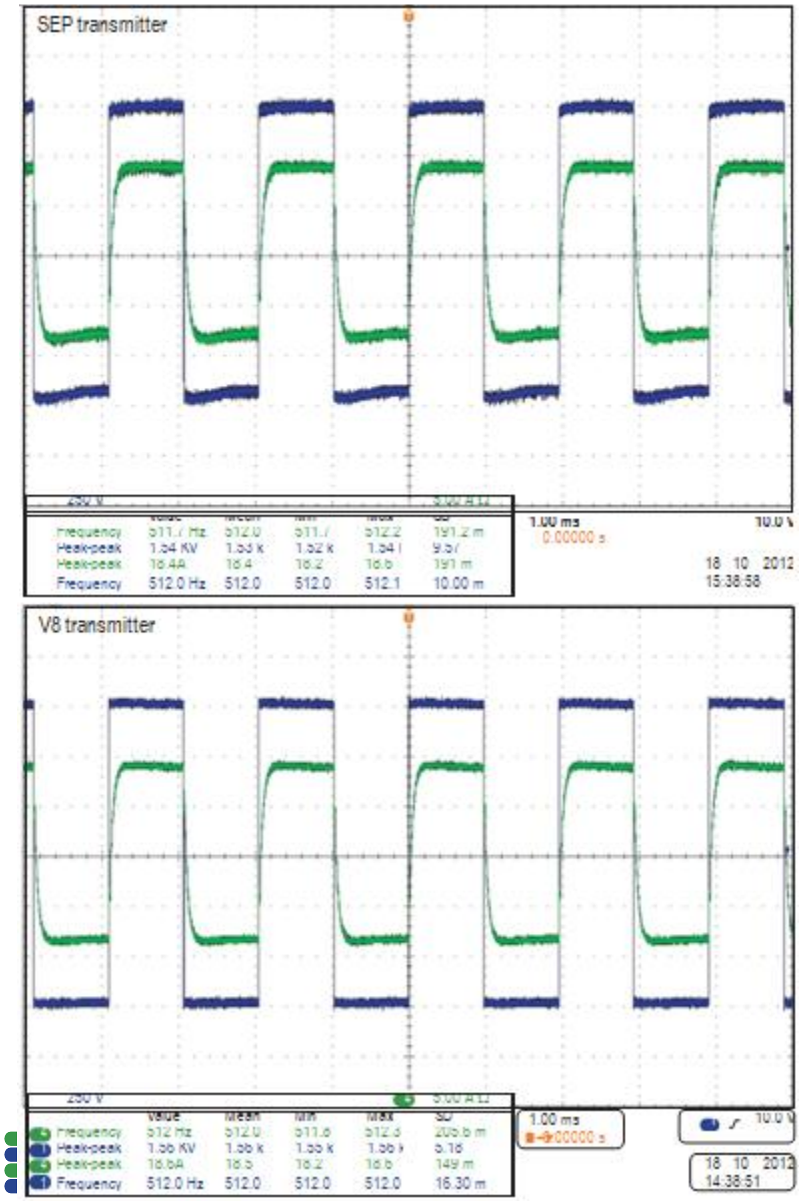

Figure 3: Voltage and current waveform of the SEP (top) and V8 (bottom) transmitters in Sikar District

The blue lines represent the voltage, while the green lines track the current waveform.

The field data acquired by both the SEP and V8 systems were good in this location. Due to the large number of sounding points, only a representative example of the electric and magnetic field amplitude curve lines are shown in this manuscript. Figure 4 contains the sounding curves at point 2510 of Line 2, with an EM signal from the V8 transmitter. We found that the electric field and magnetic field results from the SEP and V8 receivers were a good match. Figure 5 reveals that the apparent resistivity results from the SEP and V8 systems generally coincided with each other as well.

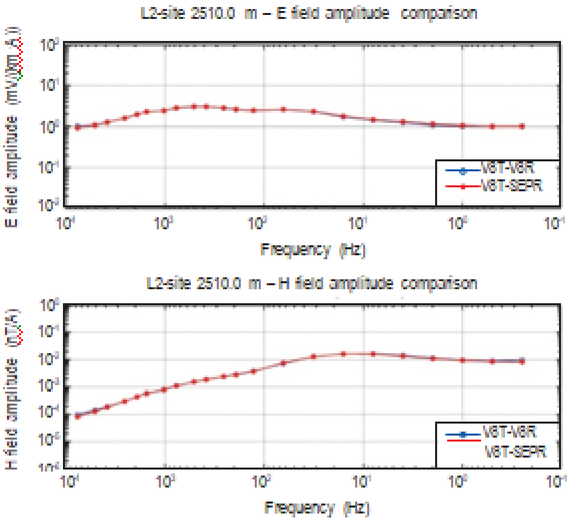

Figure 4: Electric field and magnetic field strength comparisons between the V8 (blue) and SEP (red) systems at site 2510 of Line 2. All signals were sent by the V8 system transmitter.

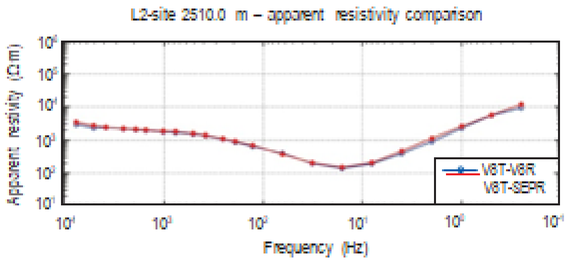

Figure 5: Comparison of apparent resistivity as detected by the V8 (blue) and SEP (red) systems at site 2510 of Line 2. All signals were sent by the V8 system transmitter

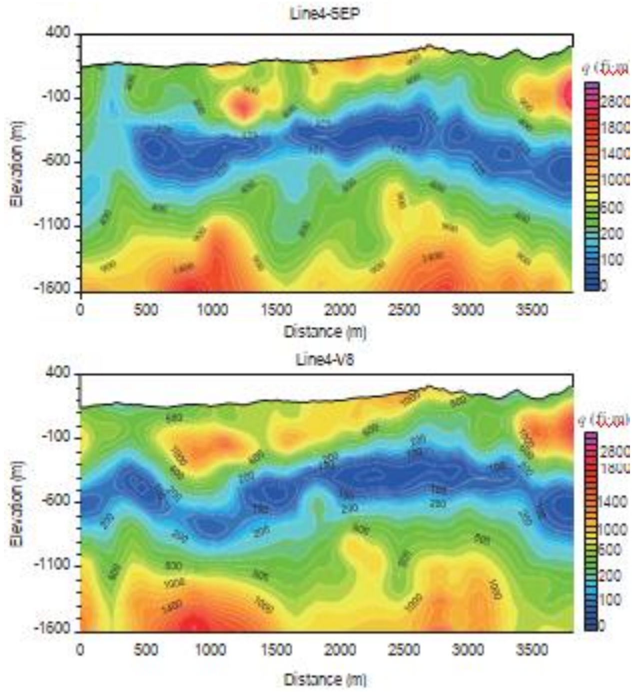

Figure 6: Profiles of the inversion results for the SEP (top) and V8 (bottom) systems based on data from Line 4.

A careful examination of Figure 6 reveals some inversion differences between SEP and V8; however, the results are broadly similar to each other.

To improve our data analysis, we calculated the root mean square (RMS) for all sounding sites with the V8 system results assumed to be the true values, using the standard formula

The SEP inversion results for Line 2 along with JK-1 well logs are shown in Figure 7. According to the borehole logs, five geoelectrical layers exist at this location. The first layer comprises sandstone, siltstone, and gluconite with a thickness of approximately 390 m, and the second layer comprises conglomerate, including bauxite. The third layer's resistivity is very low, comprising mudstone with a coal bed. The fourth layer' s resistivity is high due to the presence of limestone, crystalline limestone, and skarn, and the deepest layer is granite, which extends to a depth greater than 1700m. This inversion result clearly reflects the underground lithological differences beneath this transect, and it neatly accords with the well log data; in particular, responding to the low-resistance coal seam at an

$$R_{RMS}=\sqrt{\sum_{i=1}\left\{\left|\frac{R_{SEP}-R_{V8}}{\left(R_{SEP}+R_{V8}\right)/2}\right|\right\}^{2}}$$

where R_{SEP} is the apparent resistivity from the SEP system, R_{V8} is the apparent resistivity of the V8 system, and N is the number of frequencies measured. Each sounding site was considered to have good data if its $R_{RMS} \leq 0.7$. We collected data from 744 total sounding points in this survey area, of which 631 met our quality criteria.

One-dimensional inversion (Routh and Oldenburg, 1999) was applied for each survey line; Figure 6 presents the inversion results for the SEP and V8 data from Line 4. elevation of about –600 m.

SEP field tests in Narsingpur, Gumansingh dhani

After the experiment in Liaoning province, the SEP system was optimized and its performance improved significantly. To demonstrate that the SEP system has

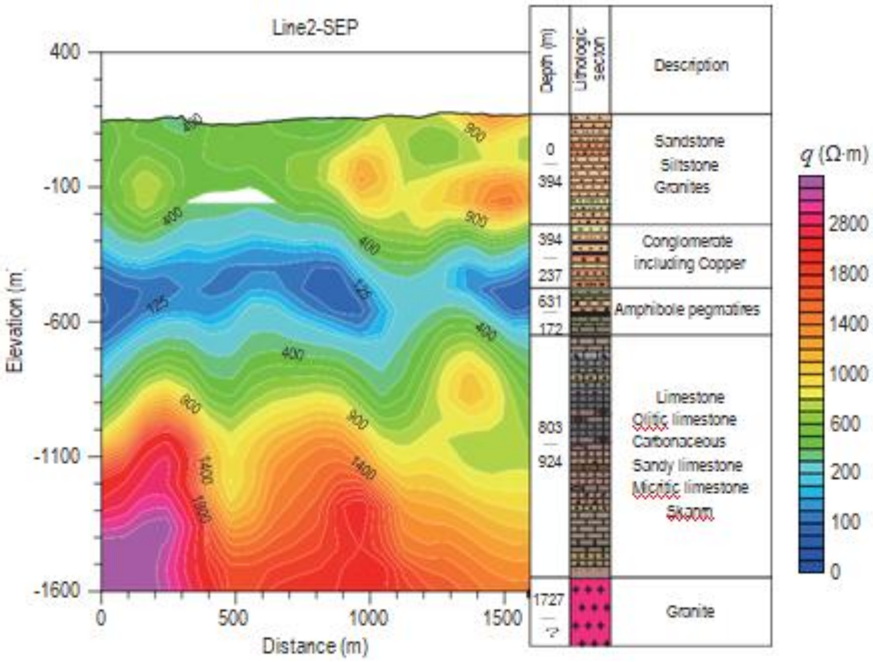

Figure 7: SEP inversion results and JK-1 well log data

reached the requirements for field usage, we conducted a exploration work in Sikar District Rajasthan Design of survey lines and field work. We conducted 14 linear surveys with an azimuth of 72˚ and two perpendicular linear surveys with an azimuth of 342˚ (Figure 8). The distance between each of the 14 transects was 500 m, and the length of each line was 3240 m. The two perpendicular survey lines were each 7290 m long and were 500 m from each other. The total length of all the survey lines was 60 km, across which 1998 sounding points were collected. One SEP transmitter and 30 SEP receivers were used in this area; in addition, one V8 receiver was used for survey lines L7, L14, and L16.

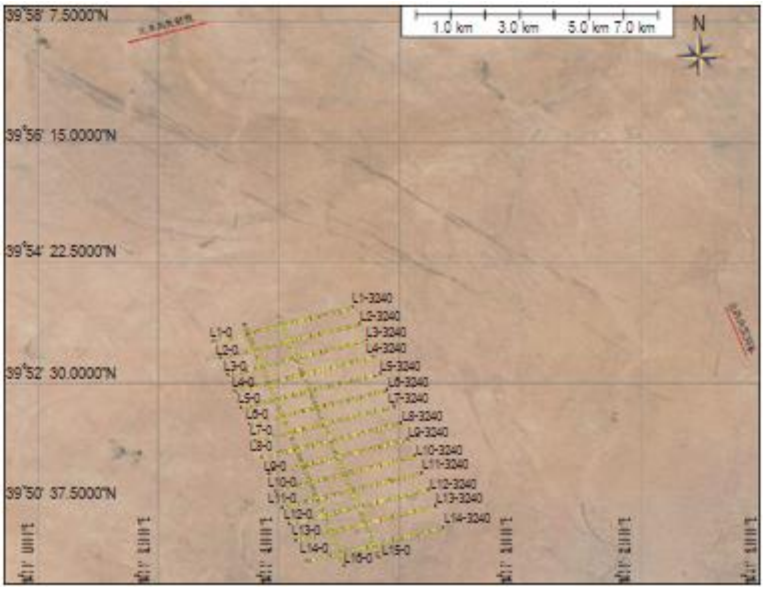

Figure 8: Exploration survey lines in Sikar District

Yellow lines indicate survey transects, and red lines denote the locations of the transmitters.

Field test results

A series of improvements had been applied to the SEP transmitter by the time of this test, including the optimization of the software and architecture. The original 16-Hz waveform from the SEP transmitter was now very stable and highly accurate (Figure 9), which indicated a significant improvement in performance.

The quality of the field data was good in this survey area, and the data curve was smooth. The strength of the electromagnetic field, the apparent resistivity, and the impedance phase are shown in Figure 10. Because the two types of magnetic sensors respond differently at very low frequencies, we observed a small difference between the two systems below 1 Hz in the magnetic field data. Within the conventional band for the Exploration method, all curves were essentially the same, and they all reflected good quality.

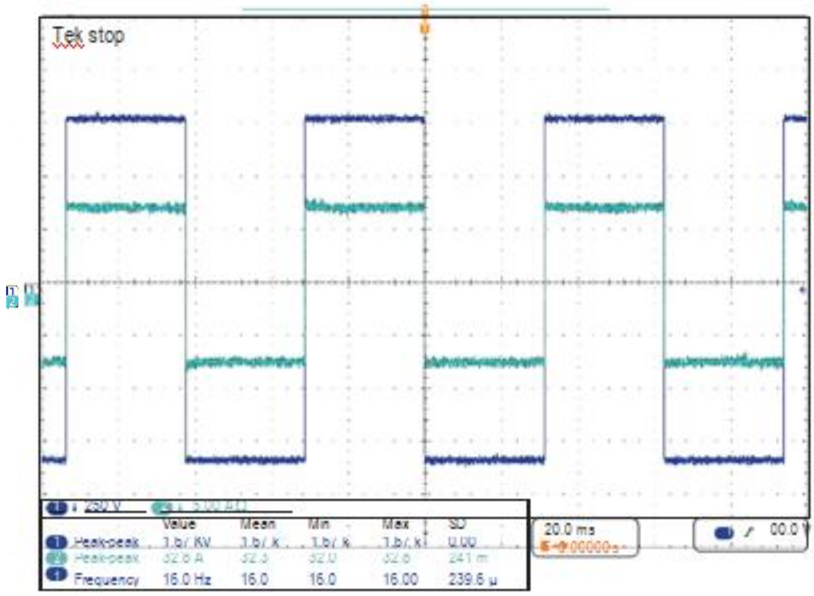

Figure 9: Voltage and current waveforms for SEP transmitters in Narsingpur.

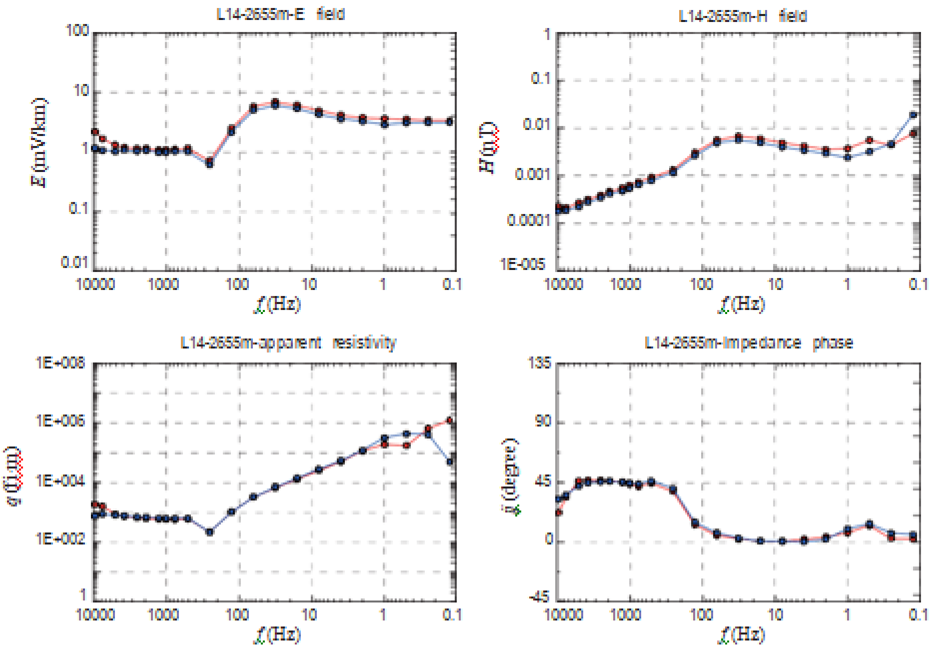

Figure 10: Field data for electrical and magnetic fields, apparent resistivity, and impedance for the SEP and V8 receivers

The red and blue lines indicate the SEP and V8 data, respectively.

The quality of the raw data was very good in the field; thus, we were able to directly use the data to complete the inversion. Figures 11 and 12 show the inversion results for SEP and V8 for Line L07 and Line L16, respectively. The differences between the inversion results from SEP and V8 are minor. There are three major resistivity layers in the inversion profile: the resistivity of the first layer is relatively low, the resistivity of the second layer is approximately 4000 Ω·m, and the third layer is a high- resistivity bedrock. The similarity of these inversion results reinforces the reliability of the SEP system.

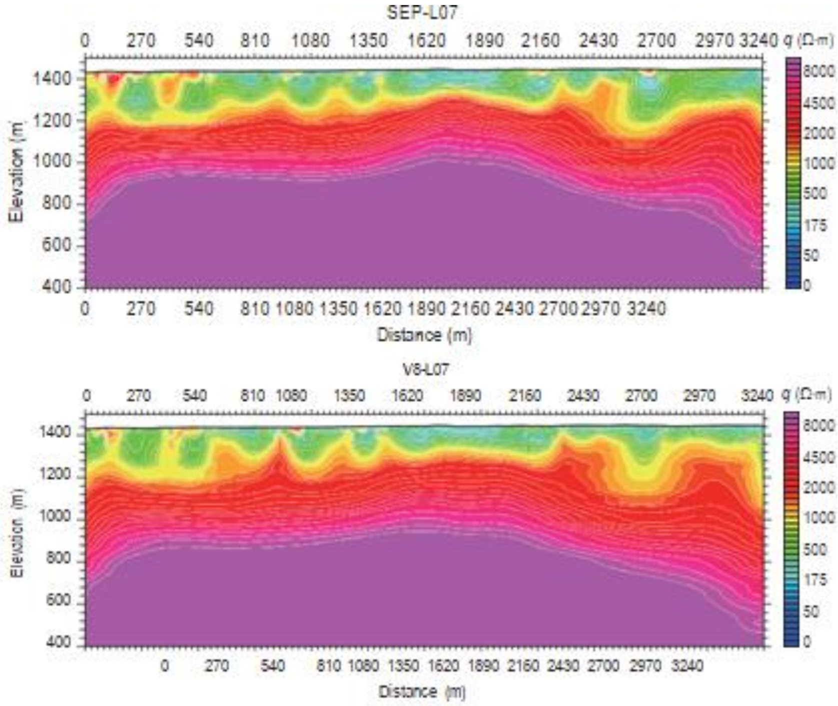

Figure 11: SEP (top) and V8 (bottom) inversion results for Line L07

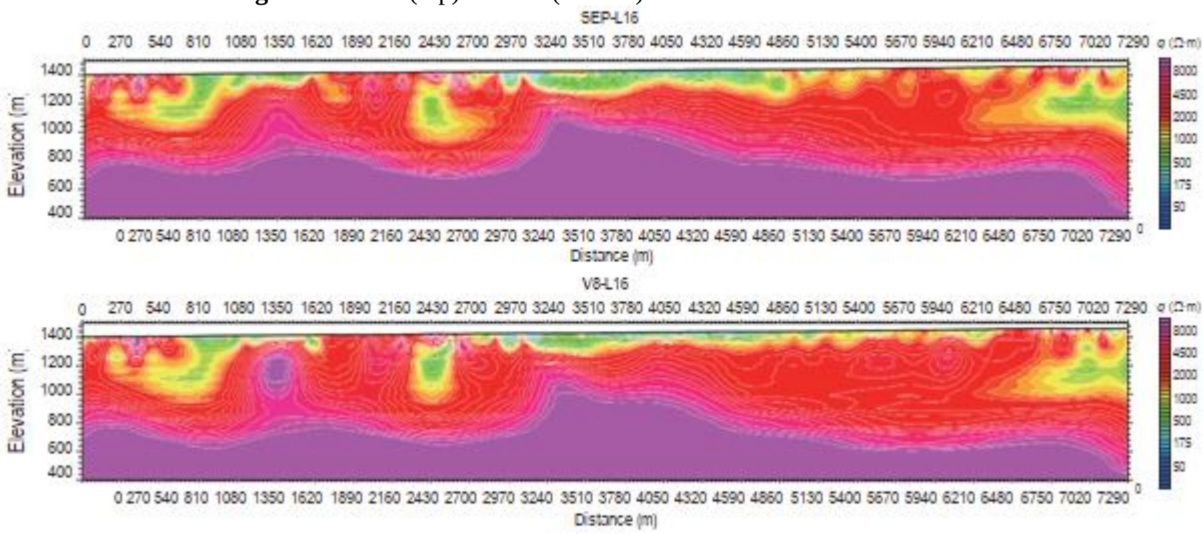

Figure 12: SEP (top) and V8 (bottom) inversion results for Line L16

3. Conclusions

System integration and optimization field tests are very important for the development of electromagnetic sounding equipment such as the Rajasthan SEP system. We identified problems with the system that emerged on the field and not in the lab; in addition, the performance of the whole system was effectively evaluated in a field environment.

The first system-level field test was performed in the Narsingpur area; it comprised comparisons with a high-end commercial instrumentation system. After this field test, a series of optimizations were applied to the SEP system. A subsequent field test in the Gumansingh Dhani area showed that the upgraded SEP system was effective, stable, and reliable.

The SEP system has now been successfully tested on the field. Field tests and comparisons show that, with its high-power transmitter and high-sensitivity magnetic sensor, the SEP system can acquire quality field data, and the performance of the upgraded SEP system has reached levels comparable to commercial instruments.

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