The Laboratory Demonstrator System (LDS)

Applicable for the Electrical Resistivity Method

USERS OPERATIONAL MANUAL

November, 2020

Asmara, Eritrea

1. Introduction

This manual is intended to guide the user to successfully operate the software for the laboratory demonstrator system (LDS). The user is assumed to have read the paper entitled "A new Laboratory Demonstrator System for the electrical resistivity method: System description and preliminary results" (Ogubazghi et al., 2020).

Operation of the system involves, configuring, and making choices to produce desired results. These are briefly described below.

2. Preparing the operation environment of the system

The LDs source program is written in the Fortran programing language. The source code runs in all windows platforms within Code::Blocks; an open-source cross-platform Integrated Development Environment (IDE). Gnu FORTRAN compiler is selected from the different compilers available within the Code::Blocks. The IDE is freely available at http://www.codeblocks.org/downloads. The program also calls Gnu plot, a command-line program that can generate two-and three-dimensional plots of functions, data, and data fits for the display of the various outputs of the LDS. It is freely available at http://www.gnuplot.info/download.html.
Size of the software: The size of the Code::Blocks and Gnu plot combined is about 202 MB.
Recommended hardware: The authors have used the system on Windows based desktop and laptop environments. Processors of 1 GHz or more; RAM of 1 GB or higher; display resolution of 800 x 600 or better, are recommended.
Note: It is important to put the file of the source program, and the files config and profile be in the same directory as the IDE directory.

For more details of the IDE system and the Gnu plot software please refer to their respective manuals, which are located in their respective websites. Also

3. Configuring the system

3.1. Basic setup

As a background, the generalized electrical resistivity data acquisition system is presented. This is shown in Fig. 1. Electrical current is injected by means of the electrodes IL and IR, and the potential electrodes VL and VR are used to measure the resulting voltage across them. The current electrodes get their supply from the battery.

In order to run the system successfully, the executable version of the LDS program, *lds.exe*, and the files *config* and *profile* must be present at the same directory. The program starts by double clicking at the *lds.exe* file.

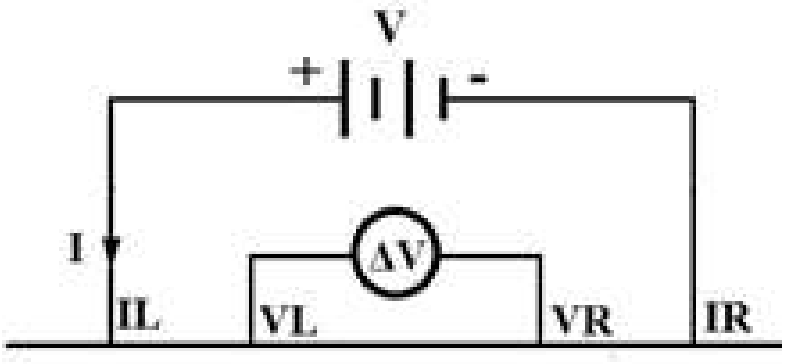

Fig. 1. The basic data acquisition setup.

3.2. Configuring the system

Configuring the system involves initially setting the positions of the current and potential electrodes, set the value of V, and the values of the variables in the model that represent the subsurface, namely h, *m*, and *n* (Ogubazghi et al., 2020). It also sets the values of the resistances of the *m* rows.

This is facilitated by editing the file *config*.

3.3. Details of the *config* and *profile* files

The details of the config file are given in Table 1. The values of the variables are set offline, and the Program reads this file every time it is run, thus initially configuring the system. The details of the profile file are given in Table 2. Similarly, the values of the profile variables are set offline and the file is read when the Program is run, initially configuring the system.

Table 1. Details of the *config* file.

Variables	IL	IR	VL	VR	*n*	*m*	h	V
Values	24	27	25	26	50	30	2.0	12.0

From Table 1, the values of the variables are just below them. As an example, the values of IL and IR are 24 and 27, respectively. The values of the electrode positions

may be varied at runtime, but the values of the rest of the variables in the Table can't be modified online.

Table 2. Details of the *profile* file.

Variables	p_1	p_2	p_3	p_4	p_5	p_6	p_7	…	p_{m-1}	p_m
Values	100	100	200	200	200	200	200	…	200	200

The values of the profiles (layers), p_1, p_2, etc. are given just below them. As an example, the values of p_1, p_2, and p_3 are 100, 100, and 200, respectively. The values in the *profile* file can't be modified at runtime.

This completes the initial configuration process. Running the Program is given next.

4. Operating the Program

4.1. Modifying initial settings

This phase of the Program allows the user to modify the initial configuration of the system. This is done in the following manner. Modeling it.

First the Program must start by double clicking on the *lds.exe* file. The message: 'Input date' appears. Input the date as: '21/09/2020'; which translates to 21 September 2020. It is important to use the ' ' marks.

After this, the values of config file are displayed, and a message appears: 'If Wenner config is desired, input 1'. Enter 1 if Wenner configuration is desired, else enter any other number for Schlumberger configuration. Following this, the message 'Input deviation from the initial setting:' appears. Enter the deviation Δd. For Schlumberger configuration, this has the effect of reducing IL by Δd and increasing IR by Δd. For the Wenner configuration, this changes the electrode spacing 'a' by Δd. The details are given in the next section.

Following this, the message: 'Input horizontal displacement' appears. Enter Δs, which has the effect of changing the positions of all 4 electrodes equally. After this, the updated positions of the 4 electrodes appear, together with the message: 'If correction is desired enter 1 and input correct values, or another number to continue'. If it is not OK, input the correct values, else if it is OK, the modification is accepted and that is the final setting which will be used by the Program. An elaboration of the operations with Δd and Δs is given next.

4.2. Some elaborations on the operations with Δd and Δs

Most of the time the values of the variables in the *config* file are set as in Table 1. However, the electrode positions are modified during runtime. This is facilitated by defining the DEV and DIS operations. The DEV operation expands the electrode spacings by increments of Δd from the initial setting without changing the center of the electrode system. In the Schlumberger case, this involves leaving the positions of the potential electrodes unchanged and incrementing only the current electrodes. The defining equations for this are

$$IL = IL_i - \Delta d \qquad (1)$$

$$IR = IR_i + \Delta d \qquad (2)$$

where IL_i and IR_i are the initial values and IL and IR are the modified values. In this case, Δd may have values of 1, 2, 3, etc.

For the Wenner configuration the defining equations are

$$VL = VL_i - \Delta d/2 \qquad (3)$$

$$VR = VR_i + \Delta d/2 \qquad (4)$$

$$IL = VL - (\Delta d + 1) \qquad (5)$$

$$IR = VR + (\Delta d + 1) \qquad (6)$$

where VL_i and VR_i are the initial values and VL and VR are the modified values. For this case Δd could have values of 2, 4, 6, etc. Equations 3 – 6 are valid for initial values of electrode positions as in Table 1.

With the Δs operation, all of the modified values of the above equations are modified by adding Δs (with Δs having values of ±1, ±2, ±3, …). As an example, for Δd and Δs of 8 and 5, respectively, and the initial settings of the electrodes as in Table 1, the finally modified electrode positions are: IL = 15, IR = 44, VL = 26, and VR = 35.

This completes the configuring the system. After this, the value of the *cmp* is entered and the program continues to run taking most of the time in inverting the matrix. After this, the output options follow. These are presented next.

4.3. Choosing output options

General description of outputs

Currently, the LDS has two modes for output. These are in addition to the outputs which are produced for every run and which are not influenced by the choice of the output options. The former ones are:

(i) The first mode is mode 0. In this mode, the information shown in Table 3 is saved. The file name, which is given by the experimenter, should reflect the action taken. As an example, Table 3 was saved in a file named: *rpdv00ds05_mode0_10/12/2020*. Here *rp* stands for report, and *dv* and *ds* represent the deviation Δd and Δs, respectively, and the *00* and *05* represent their respective values. These are followed by the mode chosen and the date of the experiment (these are also shown in the tables).

(ii) The second mode is mode 1, and in this case, the information shown in Table 4 is saved. The file name used for this case is: *rpdv00ds05_mode1_10/12/2020*.

There are three types of output which are produced after every run. These are:

(i) The printed outputs which are printed in the screen,

(ii) A file which contains the results of the currents through every loop of the model. This is the solution of vector **I** in equation 7 of the paper. This is recorded in file *currents*. This file is overwritten after every run unless it is saved by renaming.

(iii) A pictorial display of the current distribution in the 50 by 30 field. This may be saved by naming it in a similar manner as those for the tables. In our case, this is of the form: *pldv00ds05_10/12/2020*.

Finally, there is an output which is produced when both Δd and Δs are set to zero. This output is shown in Table 5 and is saved in a file. The file name used for this is entered by the experimenter and in our case, it is: *rpdv00ds00_10/12/2020*.

More specific explanations

As stated earlier, there are two options for the recorded version of output. Both of them record all the values (except h) of the items in the *config* and *profile* files as well as the date. The first option (option 0) gives the general output of current distribution and some computed items, while the second item (option 1) focuses on the effects of model defects.

After the Program completes the matrix inversion process, the message ‘For printing currents press 1, or from 2 – 9 to finish’ appears. Press 1 to proceed. The message ‘Input the desired output mode: 0 for normal mode, 1 for defects mode’ appears. If option 0 is chosen, the message ‘Input the name of the file for the report’ appears. A name not more than 30 characters may be entered. Following this, the program saves the report file in the operating directory, and the message ‘Do you want to write current values? (y/n)’ appears.

Table 3. Details of the file *rpdv00ds00_option0_table03*. The values of the various variables in the *config* and *profile* files are given. CR shows the values for all the currents in the middle of the electrode system, Tup and Tdw show, respectively, the sum of the currents above and including the indicated layer and the sum of the currents of the rest of the layers. up% represents the Tup value in percentage.

ELECTRICAL RESISTIVITY LDS MODEL OUTPUTS

Deviation: 0 Displacement: 0 Cmp fact: 0.780 Date: 27/11/2020

IL = 24 IR = 27 VL = 25 VR = 26 I0 (ma) = 5.34969 Bat(vlt) = 12.00

Layer	CI(Ohms)	CR(ma)	Tup(ma)	Tdw(ma)	up%
1	1000	1.9472	1.9472	3.4025	36.398
2	1000	1.1385	3.0857	2.2640	57.679
3	1000	0.6412	3.7268	1.6229	69.664
4	1000	0.3820	4.1088	1.2409	76.804
5	1000	0.2452	4.3540	0.9957	81.388
6	1000	0.1687	4.5227	0.8270	84.541
7	1000	0.1227	4.6454	0.7042	86.836
8	1000	0.0934	4.7388	0.6109	88.581
9	1000	0.0736	4.8124	0.5373	89.957
10	1000	0.0596	4.8720	0.4777	91.071
11	1000	0.0494	4.9215	0.4282	91.996
12	1000	0.0418	4.9633	0.3864	92.777
13	1000	0.0359	4.9991	0.3505	93.447
14	1000	0.0312	5.0304	0.3193	94.032
15	1000	0.0275	5.0579	0.2918	94.546
16	1000	0.0245	5.0825	0.2672	95.005
17	1000	0.0220	5.1045	0.2452	95.417
18	1000	0.0200	5.1245	0.2252	95.790
19	1000	0.0182	5.1427	0.2070	96.131
20	1000	0.0168	5.1595	0.1902	96.444
21	1000	0.0155	5.1750	0.1747	96.734
22	1000	0.0144	5.1894	0.1603	97.004
23	1000	0.0135	5.2029	0.1468	97.256
24	1000	0.0127	5.2156	0.1341	97.493
25	1000	0.0120	5.2276	0.1221	97.717
26	1000	0.0114	5.2389	0.1108	97.930
27	1000	0.0108	5.2498	0.0999	98.132
28	1000	0.0103	5.2601	0.0896	98.325
29	1000	0.0099	5.2700	0.0797	98.511
30	1000	0.0797	5.3497	0.0000	100.000

If ‘y’ is entered, currents in the various columns (from 1 to 50) could be displayed. If the chosen column is, for example 5, the value of the horizontal layer currents between node 5 and 6 are displayed, along with their sum. This may be used to explore current distribution in the 50 x 30 field of the model. If ‘n’ is chosen, a graphical display of the current distribution appears. This may be saved by pressing the ‘export’ button at the upper left of the plot and by giving a name which should be related to the saved report file. This completes the program, and a new run may be started or the program stopped by pressing return.

The contents of the outputs are shown next. Table 3 gives the detail of the tabulated results (the name of this file is: *rpdv00ds00_option0_table03)*. The plot corresponding to Table 3, saved in file: *pldv00ds00_option0_fig02* is shown in Fig. 2.

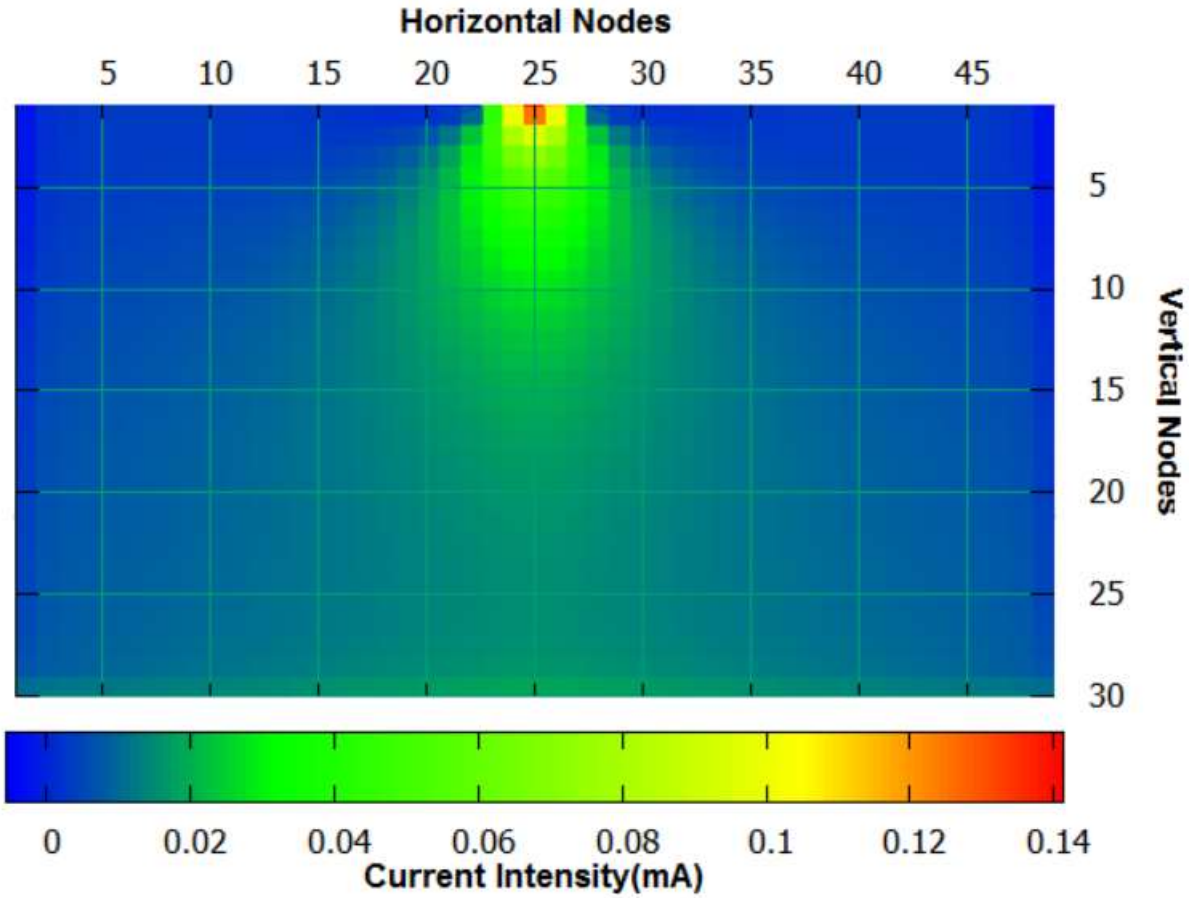

Fig. 2. Plot of the current distribution, in the 30 x 50 field of the model, corresponding to the output of Table 3.

If option 1 is chosen, the message ‘Input the name of the file for the report’ appears. A name not more than 30 characters may be entered. Following this, the program saves the report file in the operating directory, and the message ‘Do you want to

write current values? (y/n)' appears. As stated earlier, if 'y' is entered, currents in the various columns (from 1 to 50) could be displayed. If 'n' is chosen, a graphical display of the current distribution appears. This may be saved by pressing the 'export' button at the upper left of the plot and by giving a name which should be related to the saved report file. Press return to continue.
The contents of the output files for this mode are shown next. Table 4 shows the case where $\Delta s = 0$, and the case of $\Delta s = 1$ is shown in Table 4.

Table 4. Details of the file: *rpdv00ds00_option1_table04* are shown. While the other columns are similar to the corresponding values of Table 10, the L and R columns represent, respectively, the sum of the individual layer currents to the left (L) and right (R) of the middle of the electrode configuration.

ELECTRICAL RESISTIVITY LDS MODEL OUTPUTS
Deviation: 0 Displacement: 0 Cmp fact: 0.780 Date: 27/11/2020
IL = 24 IR = 27 VL = 25 VR = 26 I0 (ma) = 5.34969 Bat(vlt) = 12.00

Layer	CI(Ohms)	L(ma)	R(ma)	CR(ma)
1	1000	-0.6864	-0.6864	1.9472
2	1000	-0.2827	-0.2827	1.1385
3	1000	-0.0354	-0.0354	0.6412
4	1000	0.0922	0.0922	0.3820
5	1000	0.1579	0.1579	0.2452
6	1000	0.1930	0.1930	0.1687
7	1000	0.2122	0.2122	0.1227
8	1000	0.2227	0.2227	0.0934
9	1000	0.2280	0.2280	0.0736
10	1000	0.2301	0.2301	0.0596
11	1000	0.2299	0.2299	0.0494
12	1000	0.2283	0.2283	0.0418
13	1000	0.2257	0.2257	0.0359
14	1000	0.2223	0.2223	0.0312
15	1000	0.2184	0.2184	0.0275
16	1000	0.2142	0.2142	0.0245
17	1000	0.2097	0.2097	0.0220
18	1000	0.2052	0.2052	0.0200
19	1000	0.2006	0.2006	0.0182
20	1000	0.1961	0.1961	0.0168
21	1000	0.1917	0.1917	0.0155
22	1000	0.1874	0.1874	0.0144
23	1000	0.1833	0.1833	0.0135
24	1000	0.1794	0.1794	0.0127
25	1000	0.1758	0.1758	0.0120
26	1000	0.1725	0.1725	0.0114
27	1000	0.1695	0.1695	0.0108
28	1000	0.1670	0.1670	0.0103
29	1000	0.1649	0.1649	0.0099
30	1000	1.2762	1.2762	0.0797

Table 5. Details of the file *rpdv00ds01_option1_table05*. All are similar to the corresponding values in Table 4. CR0 represents the currents for Δs = 0. It is given for comparison purposes. Ds% represents the percentage difference between CR and CR0. Note that the difference in the currents is not visible here, but exists in the values which are given to a precision of fractions of nano-amperes.

ELECTRICAL RESISTIVITY LDS MODEL OUTPUTS
Deviation: 0 Displacement: 1 Cmp fact: 0.780 Date: 27/11/2020
IL = 25 IR = 28 VL = 26 VR = 27 I0 (ma) = 5.34969 Bat(vlt) = 12.00

Layer	CI(Ohms)	L(ma)	R(ma)	CR0(ma)	CR(ma)	Ds%
1	1000	-0.6924	-0.6797	1.9472	1.9472	0.0001
2	1000	-0.2886	-0.2761	1.1385	1.1385	0.0002
3	1000	-0.0412	-0.0290	0.6412	0.6412	0.0004
4	1000	0.0866	0.0983	0.3820	0.3820	0.0007
5	1000	0.1526	0.1638	0.2452	0.2452	0.0012
6	1000	0.1880	0.1985	0.1687	0.1687	0.0017
7	1000	0.2077	0.2173	0.1227	0.1227	0.0023
8	1000	0.2186	0.2273	0.0934	0.0934	0.0030
9	1000	0.2243	0.2321	0.0736	0.0736	0.0036
10	1000	0.2268	0.2336	0.0596	0.0596	0.0043
11	1000	0.2272	0.2329	0.0494	0.0494	0.0049
12	1000	0.2260	0.2308	0.0418	0.0418	0.0054
13	1000	0.2239	0.2276	0.0359	0.0359	0.0057
14	1000	0.2210	0.2237	0.0312	0.0313	0.0059
15	1000	0.2176	0.2193	0.0275	0.0275	0.0058
16	1000	0.2138	0.2145	0.0245	0.0245	0.0054
17	1000	0.2098	0.2096	0.0220	0.0220	0.0048
18	1000	0.2057	0.2046	0.0200	0.0200	0.0038
19	1000	0.2015	0.1996	0.0182	0.0182	0.0024
20	1000	0.1973	0.1947	0.0168	0.0168	0.0006
21	1000	0.1932	0.1899	0.0155	0.0155	-0.0017
22	1000	0.1892	0.1853	0.0144	0.0144	-0.0043
23	1000	0.1854	0.1809	0.0135	0.0135	-0.0074
24	1000	0.1818	0.1768	0.0127	0.0127	-0.0108
25	1000	0.1784	0.1729	0.0120	0.0120	-0.0146
26	1000	0.1753	0.1694	0.0114	0.0114	-0.0187
27	1000	0.1725	0.1662	0.0108	0.0108	-0.0229
28	1000	0.1701	0.1635	0.0103	0.0103	-0.0273
29	1000	0.1682	0.1614	0.0099	0.0099	-0.0317
30	1000	1.3095	1.2402	0.0797	0.0796	-0.0360

Note that the symmetry is perfect in Table 4 and slight deviations exist in Table 5. For the case of Table 4, the electrode spacings are symmetrical with respect to the middle (between nodes 25 and 26) of the electrode setup. For each layer, this is verified by summing the currents of the horizontal branches to the left (L) and to the right (R) of the middle of the setup. When Δs = 0, in addition to the normal results output file, another file named *DEV0* file is created and saved. For other values of Δs, the program reads the file *DEV0*, and it produces the output file shown in Table 5. In this case, symmetry is lost progressively, deteriorating in a manner proportional to the value of Δs. The extent of current deviation from the value at Δs = 0, expressed in percentage, is indicated in Table 5. Note that after a change of Δv, a new value of

DEV0 should be obtained by setting Δs to 0. To do this, the ***old DEV0 file should be deleted before the program is run, otherwise a run-time error occurs***.

The plot corresponding to table 4 is the same as that of Fig. 2. The corresponding plot for table 2 is shown in Fig, 3. There is only a very small difference from that of Fig. 2.

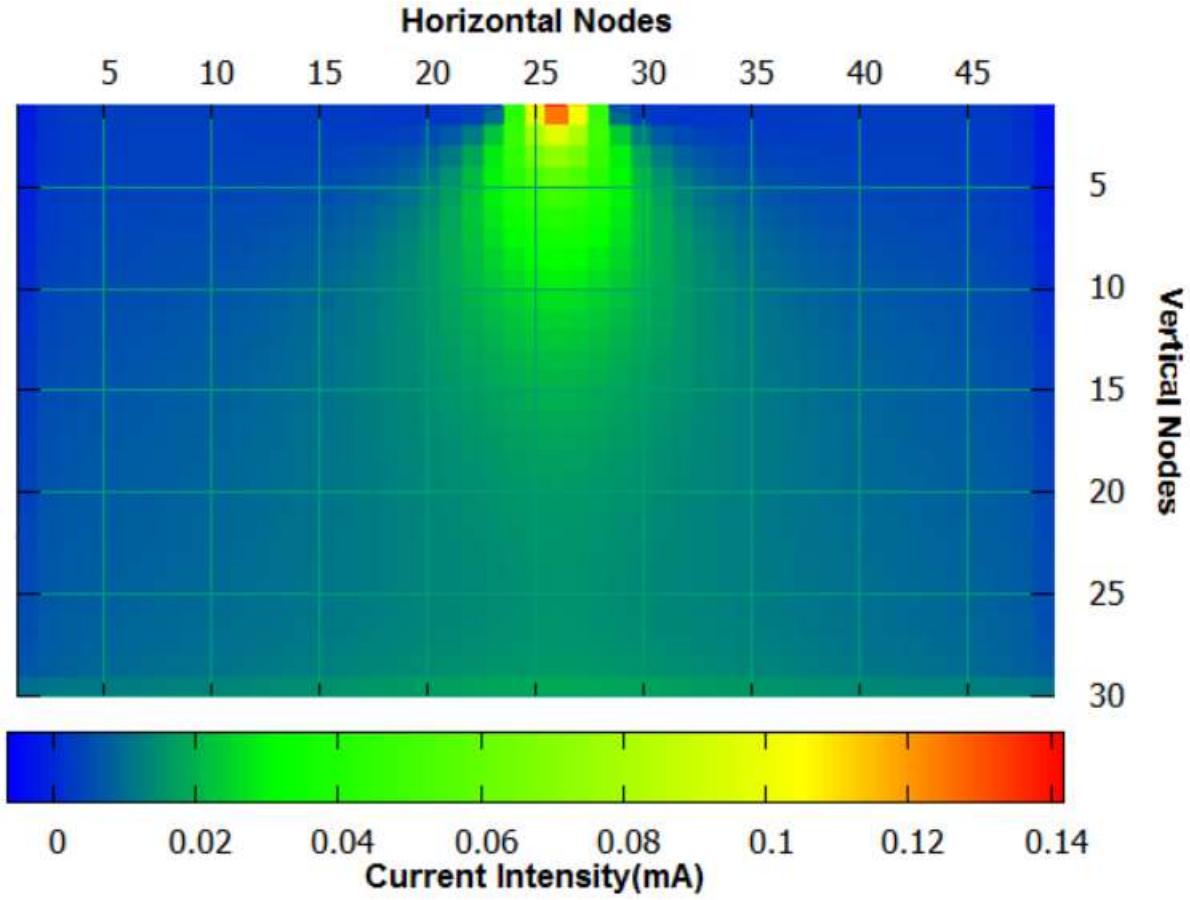

Fig. 3. Plot corresponding to the case of Table 5.

5. Commonly encountered errors

There are two errors that are frequently encountered. The first is when the *config* or the *profile* files are physically present in the working directory but are not in *word pad*. This can be remedied by opening a new *word pad* file and putting the details by hand (as this does not take much time it is safer than copying and pasting).

The second error is when the Program is required to save a new *DEV0* file and the old *DEV0* file has not been deleted. This is remedied by deleting the old file and restarting the Program.

When there are other errors, there is often a hint that is given and corrective actions could be taken based on this.