THE EFFECT OF PROXIMITY OF EARTHING CABLE AND POWER CABLES ON THE OPERATION OF EARTH FAULT PROTECTION UNIT AND CATHODIC PROTECTION

Daud. M. Jasim
Electrical power department/ Al-musayab –Tech.-college

Abstract

This work discusses the effect of proximity between the grounding cable and power cables of high hp 3-ph induction motor, on the operation of the unit of protection against earth fault current and on the system of cathodic protection of the pipes in deep wells, due to high circulating current of grounded cable, induced by the magnetic flux of a 3-ph current of induction motor because of the proximity effect.

The work contains practical beneficial experiments, in the work site, for measuring circulating currents, theoretical analysis, useful Conclusions and a very useful recommendation to the engineers deal with this field. It is shown that the reason of circulating current in the earthing cable and the cathodic protection cable is the neighboring of earthing cable to the power cables.

Keywords: Proximity effect, Grounding cable, Earth fault current, Cathodic protection, Magnetic flux

تأثير تقارب الموصل الارضي وموصلات القدرة على عمل وحدة الحماية ضد الخطأ الارضي والحماية الكاثودية

داود مشير جاسم
قسم الكهرباء- الكلية التقنية المسيب

الملخص

ان هذا العمل يتطرق الى تاثير التقارب بين الموصل الارضى وموصلات القدرة في المحركات الحثية الثلاثية الاطوار ذات القدرة الحصانية العالية على عمل منظومة الحماية ضد التوصيل الارضي وعلى عمل منظومة الحماية الكاثودية لانابيب الابار العميقة نتيجة التيار الدوار المتولد فى موصل التأريض بسبب الفيض المغناطيسى المتولد من التيار المار فى موصلات التغذية المسايرة للموصل الارضي. يتضمن البحث تجارب عملية مجدية في حقل العمل لقياس التيارات الدوارة وتحليلات نظرية واستنتاجات وتوصيات مفيدة جدا للمهندسين العاملين في هذا المجال. واثبت بأن سبب التيار الدوار في موصل التأريض وفي موصل الحماية الكاثودية هو مجاورة موصل التأريض الى موصلات القدرة.

Introduction

High power 3-ph induction motors, which are used in deep wells, get a power via long cables. The 3-ph current passing through the cables for high hp induction motors which are used in a deep well creates a changing magnetic field, Which induces a current in other near by conductors,(http://en.). This phenomena has a negative effect on the operation of the circuit breaker with earth fault relay which will be tripped when the motor put on line (Black et al; http://electrical 2009). Also it has a negative effect on the operation of the cathodic protection (Peabody, 2000; Morgan, 1987).

Several efforts were done by local engineers to know the reasons, and after very hard inspections they decided to consider that the motor earth cable connection is redundant as it creates a return path for undesirable induced current, with unknown reasons (Thwaites, 1997).

In this work several tests of inspections were done on a well pump motor of 250 hp with a depth of about 150 m, at which the problem of the earth protection failure had been happened, comparing the results with a theoretical analysis results, thus identifying the reason.

Region of analysis and grounding circuit of the original system:

The region of analysis is shown in **(Fig. 1)**

The values of resistances are measured between the above equipment and the copper ground grid at well head pcu substation**.** And are as follow :
R_1=0.527Ω Resistance motor casing / ground
R_2=0.64Ω gland plate (column pipe)/ground resistance
R_3=0.12Ω gland plate / motor casing resistance
R_4=0.51Ω well casing (cathodic protection cable / ground

Practical part

Testing of circulating current

Test (1): All grounds isolated ($I_1 = I_2 = I_3 = 0$A), **Fig. (2)**

Test (2): Motor casing grounded, **(Fig. 3):**
The values of circulating currents are :
I_1 = 4.7A , I_2 = 0 A , I_3 = 0 A

Test (3): (a) Motor casing grounded
(b) Gland plate grounded, **Fig. 4**
The values of the circulating currents are: (I_1 = 52.2 A , I_2 = 47.5 A, I_3= 0 A)

Test (4): motor casing grounded, gland plate grounded and cathodic protection cable grounded. **Fig. (5)**
The values of the circulating currents are : (I_1=58 A, I_2=47.5 A and I_3=10.2 A).

Test (5): Motor casin g grounded and Cathodic protection cable grounded, **Fig. (6)** the values of the circulating currents are: (I_1=9.6 A, I_2=0 A, I_3=9.5 A)

Test (6): Motor casing grounded and Gland plate connected to cathodic protection cable, both isolated from ground, **Fig. (7)** the values of the circulating currents are: (I_1=8A, I_2=6A and I_3=6 A).

Test (7): Motor casing connected to gland plate both isolated from ground, **Fig. (8)** the circulating current is : (I_1=47.5A).

Test (8): Motor casing grounded, Gland plate grounded and Motor casing connected to gland plate, **Fig. (9)** the circulating currents are: (I_1: 21 A, I_2: 16 A and I between casing cable point and grand plate equal 31 A).

Test (9): Gland plate grounded and Cathodic protection cable grounded, **Fig. (10)** the circulating currents are: (I_1=0, I_2= trace and I_3=trace)

The Installation:-

Referring to **Fig.1** of the original system we have, from the test data following results:

The test data

a- when A, B, C non grounded
(voltage w.r.t earth at A=0.25v, B=5v).

b- When only B grounded and A, C not grounded (voltage w.r.t earth of A =5v and current through B =4.7A .

c- Both A and B grounded, C not grounded
(current through A =47.5A, B=52.5A).

d- All A, B and C grounded
(current through A=47.5A, B=57.2A, C=10.2A).

e- Resistance to earth of A ≈ 0.6 Ω.

f- Resistance to earth of B ≈ 0.5 Ω.

g- Resistance between A and B = 0.1 Ω.

Analysis

As the power supply cable to pump motor is 3-ph single core, its flux will link with the pipe column and the grounding conductor thus induces an e.m.f in it. The magnitude of this e.m.f is depending on the relative location of pipe column and grounding conductor w.r.t power supply cables.The instantaneous polarity of the voltage at A and B will the same. i.e there will be a phase different of 180° between A and B voltage vectors . The phase angle between the voltage will depend upon the resistance and inductance (self and mutual) of the conductor A and pipe column.
We can simplify the installation in the following circuit, (**Fig. 13**)

From test result as e_a=0.25v, e_b=5v.
r_c: resistance of water column =0.5Ω
(measured as resistance to earth at B with C grounded)
rg: resistance between A and B =0.1Ω
(difference between e and f of test data) .
r_g: ground resistance .

The electrical circuits analysis of tests :

Test(2): With B and E shorted, i.e B grounded the potential of point O will rise to 5v, applying loop theory (B.L. Theraja 1979; William H. Hayt 2009). The current flowing through B is 5A. This will result in a potential rise of 5.25v of point A w.r.t ground. This is illustrated in the circuit shown in, (**Fig. 14**):

$$I_1 * 1 = 5 \text{ hence } I_1 = 5A \tag{1}$$

Test (3): With both A and B grounded, the current through B is 52.5A and that through A is 47.5A. The current passes through water column is 5A. (**Fig. 15**)

$(I_1-I_2)\times 1=5$ (2)

$(I_1-I_2)\times 1-0.1\times I_2=0.25$ (3)

Hence $I_1=52.5$, $I_2=47.5$

Test (4): With both A, B and C grounded the current through B is 57.5A and that through A is 47.5A and that through C is 10A. (**Fig. 16**)

$(I_1-I_2)\times 0.5=5$ (4)

$(I_1-I_2)\times 0.5-0.1\times I_2=0.25$ (5)

Hence $I_1=57.5$, $I_2=47.5$

Test (5): With B grounded, C (cathodic protection cable) grounded the current through B IS 10A and that through C is 10A also, (Fig. 17)

$I_1\times 0.5=5$ (6)

Hence $I_1=10$, $I_2=0$ (A not grounded)

Test (6): With B grounded, A connected to C (both isolated from ground) the current through B is 8.2 A and that through A and C is 6.4 A (Fig. 18)

$(I_1-I_2)\times 0.5+I_1\times 0.5=5$ (7)

$(I_1-I_2)\times 0.5-I_2\times 0.1=0.25$ (8)

Hence $I_1=8.2$, $I_2=6.4$

Test (7): With B connected to A and B, both isolated from ground the current through B is 47.5, (**Fig. 19**)

$I_1\times 0.1+0.25=5$ (9)

Hence $I_1=47.5$

Test (8): With B and A grounded, motor casing connected to gland plate the current equations are:

$(I_1-I_2)\times 1=5$ (10)

Hence $I_1-I_2=5$

$(I+I_2)\times 0.1+0.25=(I_1-I_2)\times 1$ (11)

$(I+I_2)\times 0.1+0.25=5$ (12)

Hence $I+I_2=47.5$ and $I+I_1=52.5$

If I=31A and I1=21A and I2=16A (from test 8)
Then I+I1=52A which is in a good agreement with the theoretical value and I+I2=47A which is also in a good agreement with theoretical value.
I1-I2=5A it is the current passing through earth resistance.

Test (9): Gland plate grounded, cathodic protection cable grounded ,the current through B,I1=0, through A=trace, through C=trace, (**Fig. 21**)

$$0.25-(0.1+0.5)\times I_2=0 \qquad (13)$$

Hence I_2=0.4 A

Comparison between measuring and theoretical results

The comparison between measuring and theoretical results are shown in **Table (1).**

The Results Discussion

The results of the test (2) to test (8) and the theoretical results are nearly identical and indicate that there are a circulating currents in the earthing system which lead us to conclude that there is a problem with the motor windings, while test (9) indicates that the system is operating normally (with the fact that there is no any problem in the motor windings which means that there must not be any circulating current in the earthing cable even if it is joined to the earth that means there is another reason to this circulating current. This reason is the induced undesirable current in the earthing cable due to the proximity of it with the power cable (http://en), which lead to tripping of circuit breaker by earth fault relay (http:// electrical 2009), so this earthing must be cut off but in this case the diagnoses of winding failure during the operation will be impossible and will lead to a major problem.

The results show us also that this circulating current has a direct effect on operation of a cathodic protection because this current is considered as a stray current and is free to enter an underground steel structure, corrosion can occur at the point current discharge. In severe cases, the corrosion rate can be catastrophic (Peabody 2000).

Conclusion And Recommendation

In spite of the small resistance between motor casing and ground (fluid resistance and well pipe to earth resistance).the motor casing must be joined to earth for several reasons: one is that if a leakage current of a small value passes from motor windings, this cannot be sensed with out earthing cable, and this can lead a very dangerous default in the motor winding. Second, any leakage current will have a serious problem to the cathodic protection system, which must have a constant current to protect the pipes (Peabody 2000).

We saw from the tests that the reason of circulating current is not a failure in motor windings but the induced undesirable current in the earthing cable which is caused as a result of proximity of this cable with the power cables for this reason we recommend that the earthing cable must be joined separately and a way from power cables as far as possible.

References

A.W Peabody, Control of Pipe Line Corrosion, National Association of Corrosion Engineers, Houston 2000.

B. L. Theraja, " A text-book of Electrical Technology, 1979"

Black Burn and J. Lewis " Protective Relaying Principles and Applications , 1982, "chapter 11".

http://en .wikipedia.org/wiki/proximity effect (electromagnetism).

http://electrical and electronics. Org//wp. content/ uploads/2009/ 03/ over-current-and-earth-.
Morgan, J. H. " Cathodic Protection " National Association of Corrosion Engineers (NACE) 2nd edition 1987.

Thwaites, T. J., " Circulating Current" Great Man-Made River Project, Phase I Sarir Wellfield, Bengazi, may 1997.

William H. Hayt and Steven M. Dutbin " Engineering Circuit Analysis, eight edition 2009.

Table (1) , The measuring and theoretical results

Measuring results	**Theoretical results**
Test (2) I_1=4.7A, I_2=0, I_3=0	I_1=5A, I_2=0, I_3=0
Test(3) I_1=52.2, I_2=47.5, I_3=0	I_1=52.5, I_2=47.5, I_3=0
Test(4) I_1=57.2, I_2=47.4, I_3=9.6	I_1=57.5, I_2=47.5, I_3=0
Test(5) I_1=9.6, I_2=0, I_3=9.5	I_1=10, I_2=0,I_3=10
Test(6) I_1=8, I_2=I_3=6	I_1=8.2, I_2=I_3=6.4
Test(7) I_1=47.5, I_3=I_2=0	I_1=47.5, I_3=I_2=0
Test(8) I_1=21A, I_2=16A I the current between Motor casing cable and Gland plate=31A,the current Through motor casing cable 52.2A	I+I_2=47.5A, I_1-I_2=5, I+I_1=52.5
Test(9) I_1=0, I_2=trace, I_3=trace	I_1=0, I_2=0.4, I_3=0.4

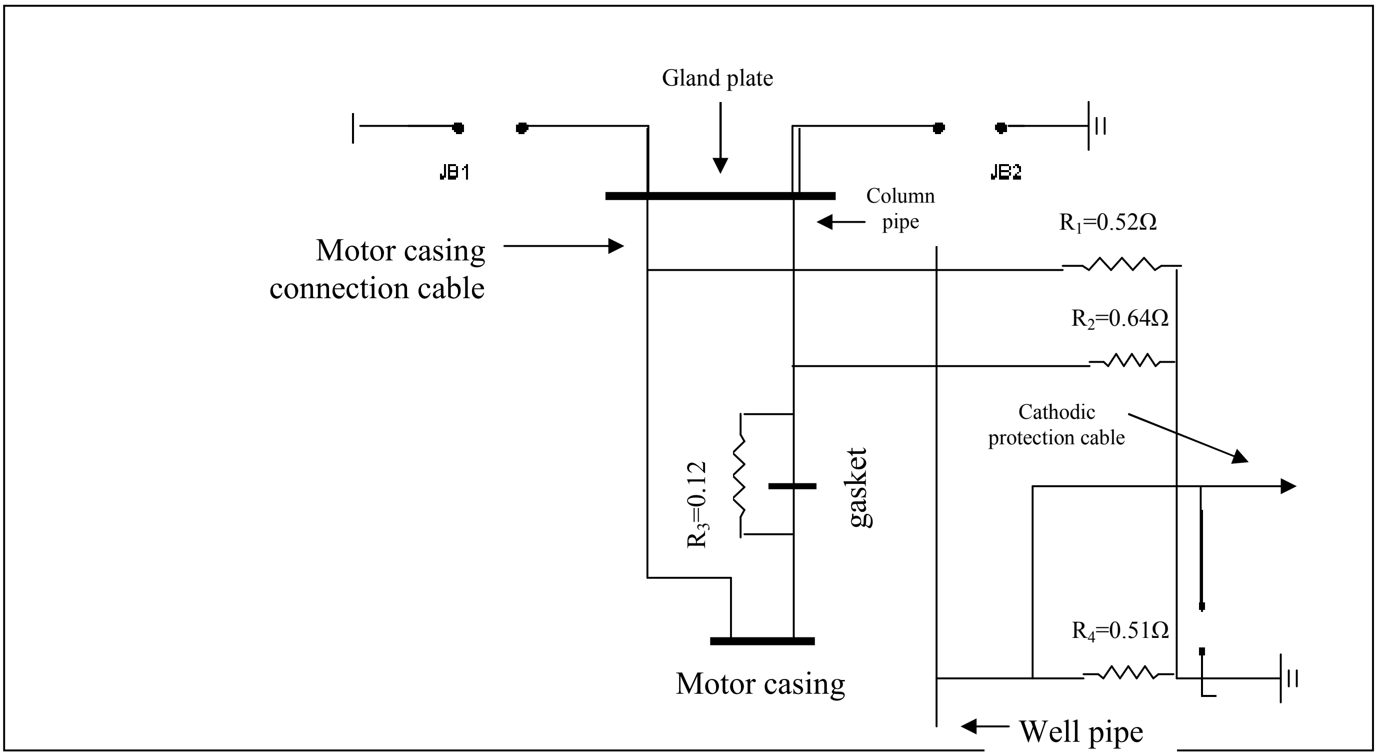

Fig. (1), The grounding cct of the original system

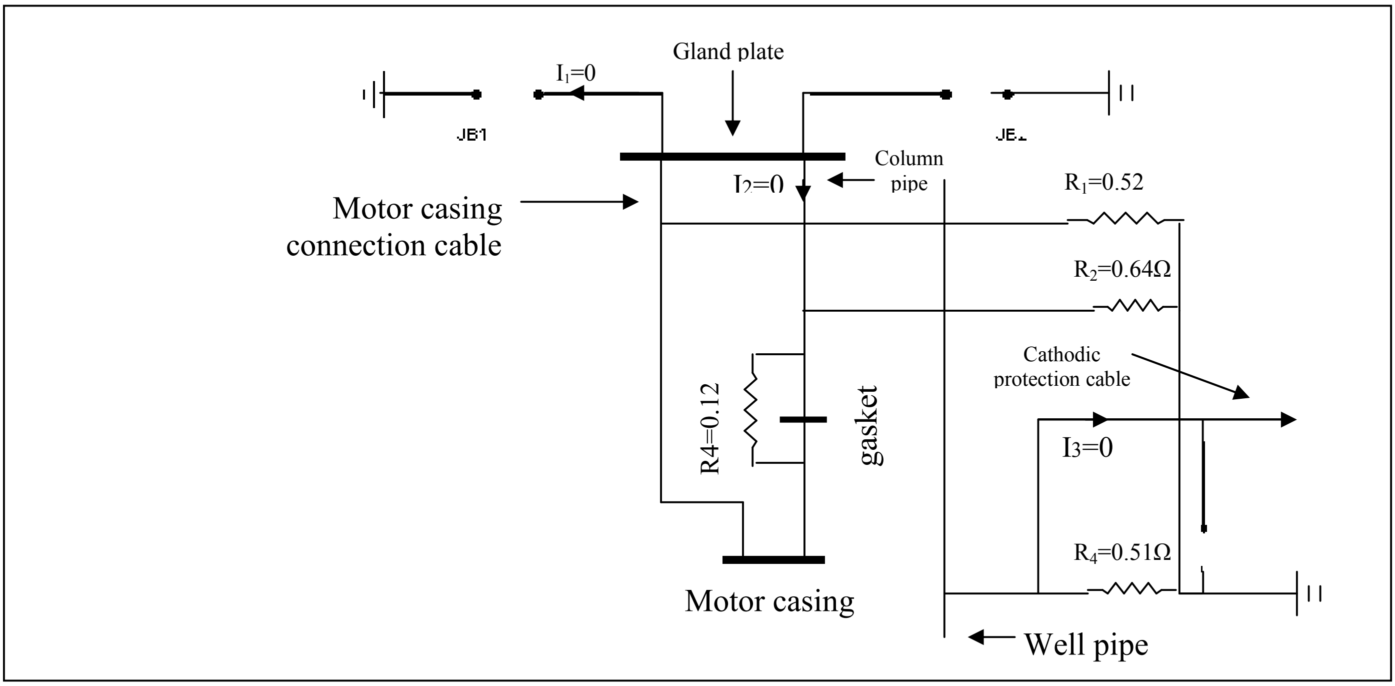

Fig. (2), The grounding cct of test (1)

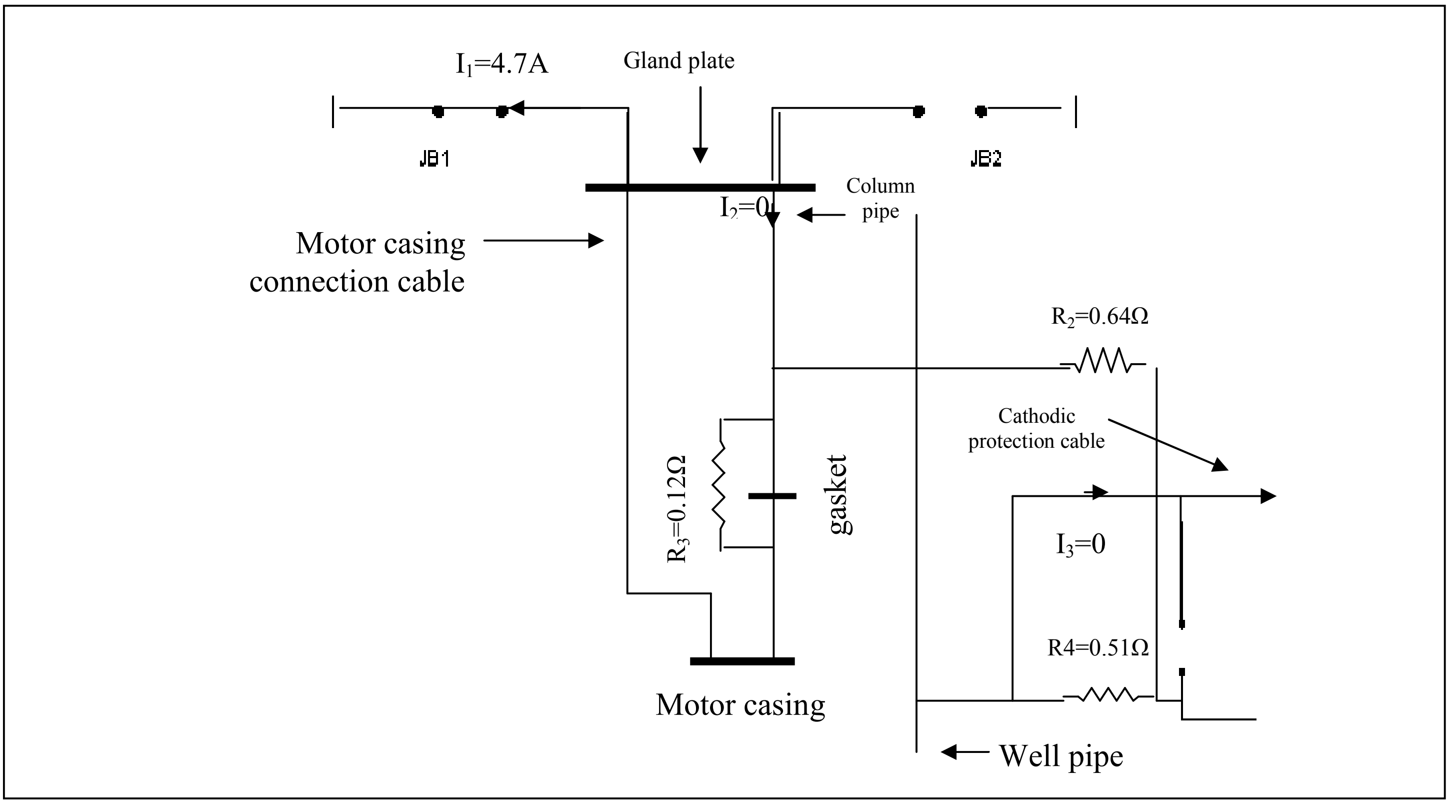

Fig. (3), The grounding cct of test (2)

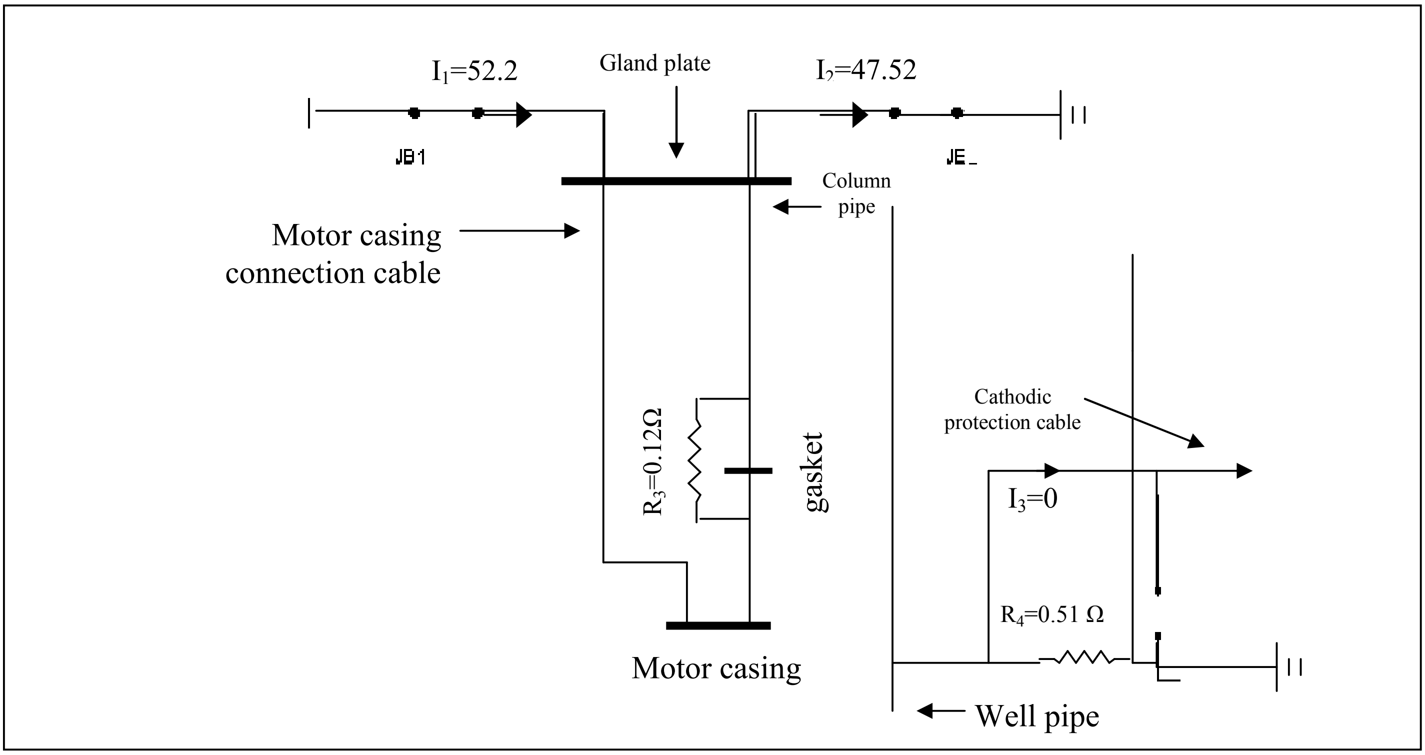

Fig. (4), The grounding cct of test (3)

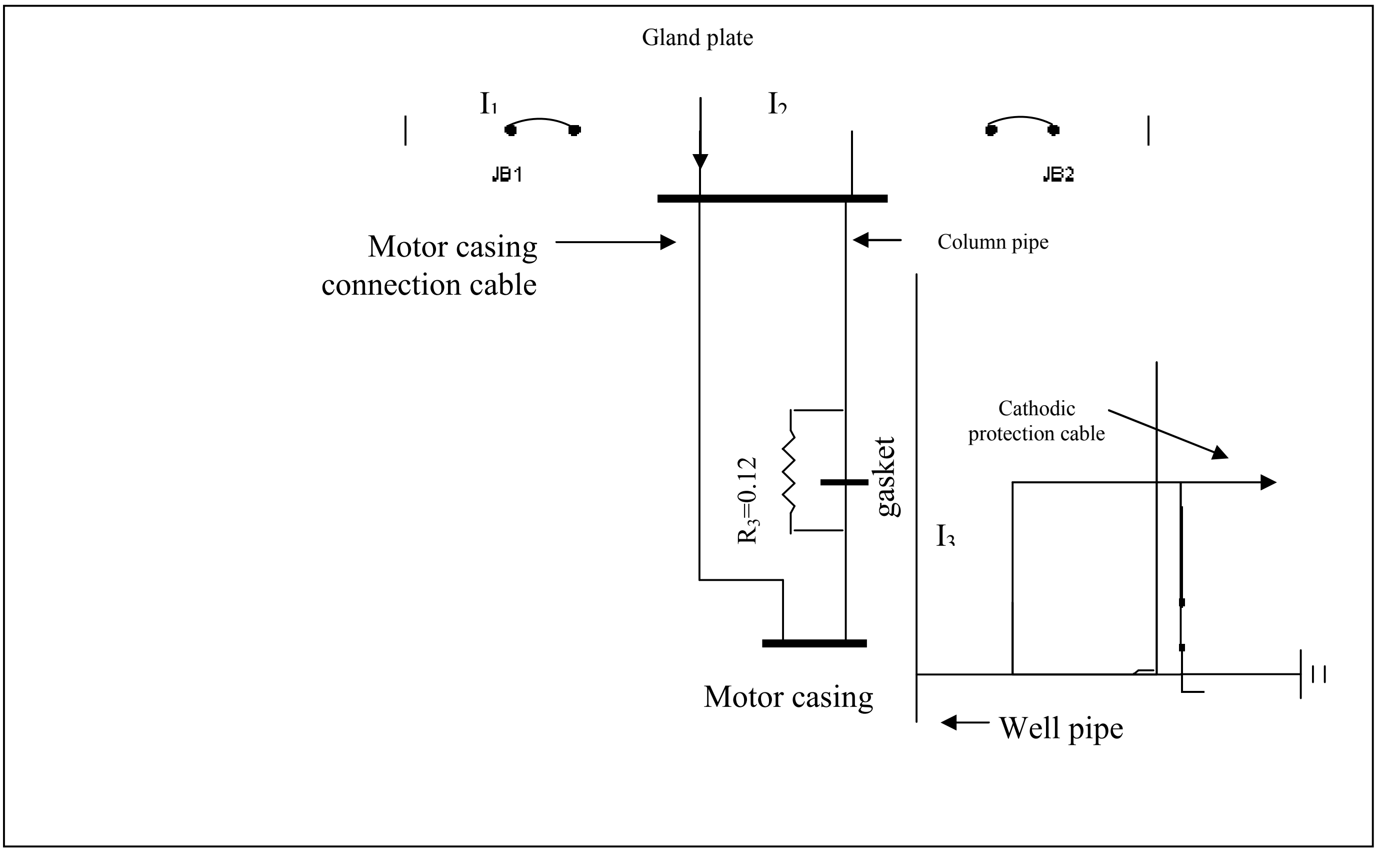

Fig. (5), The grounding cct of test (4)

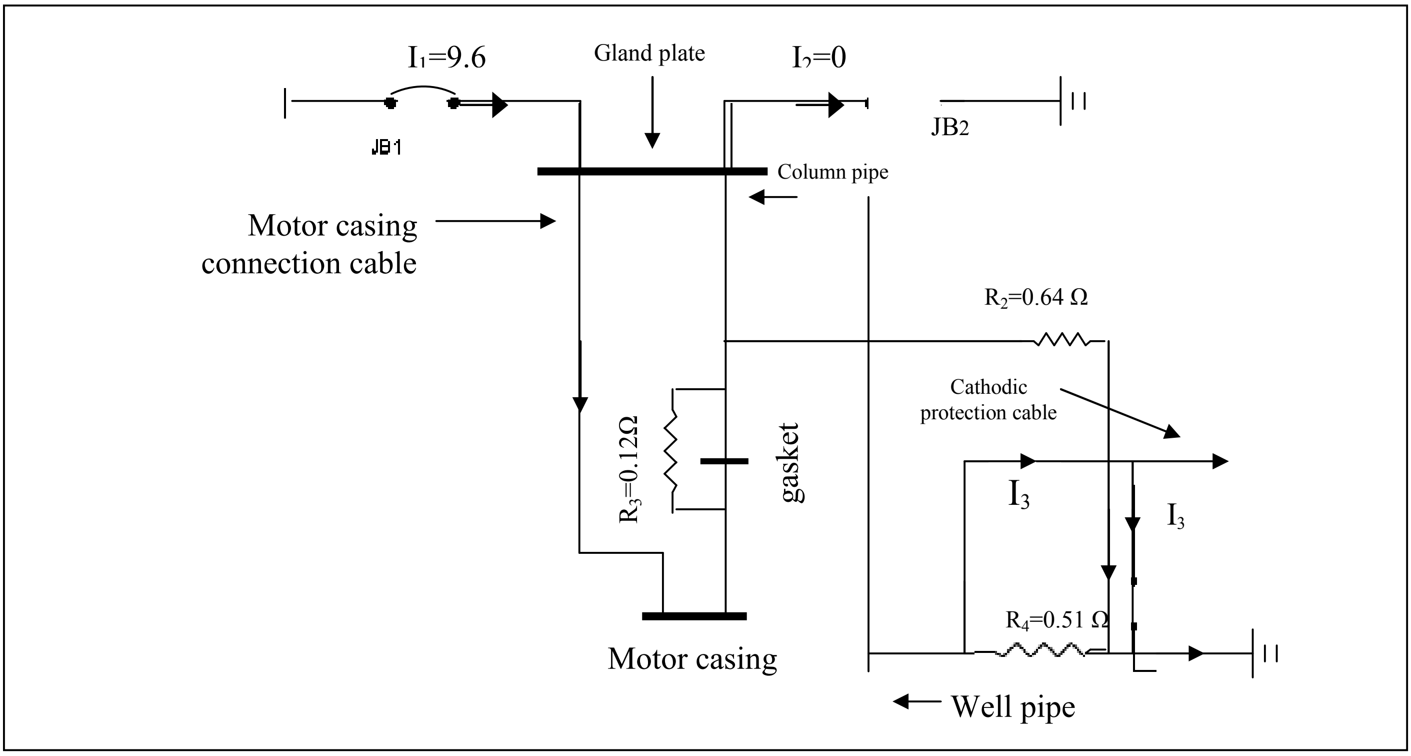

Fig. (6), The grounding cct of test (5)

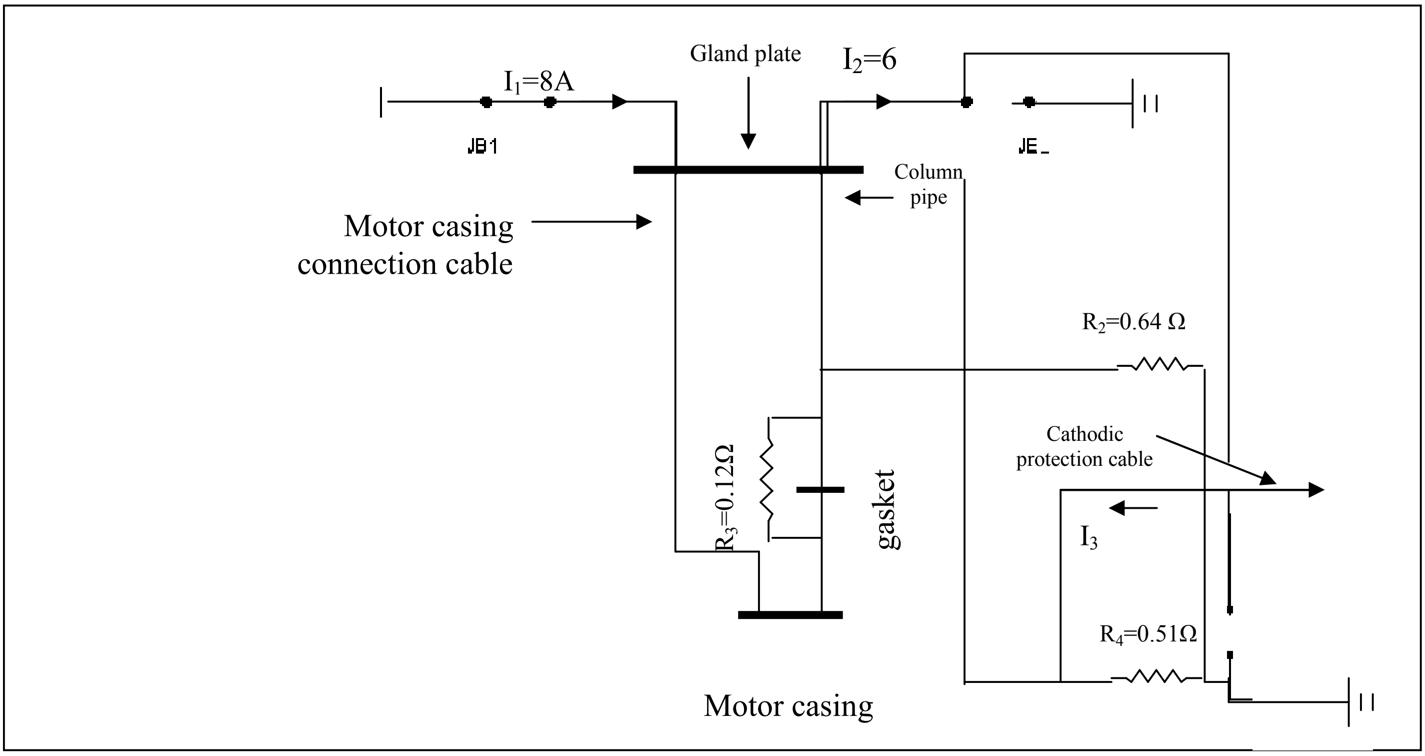

Fig. (7), The grounding cct of test (6)

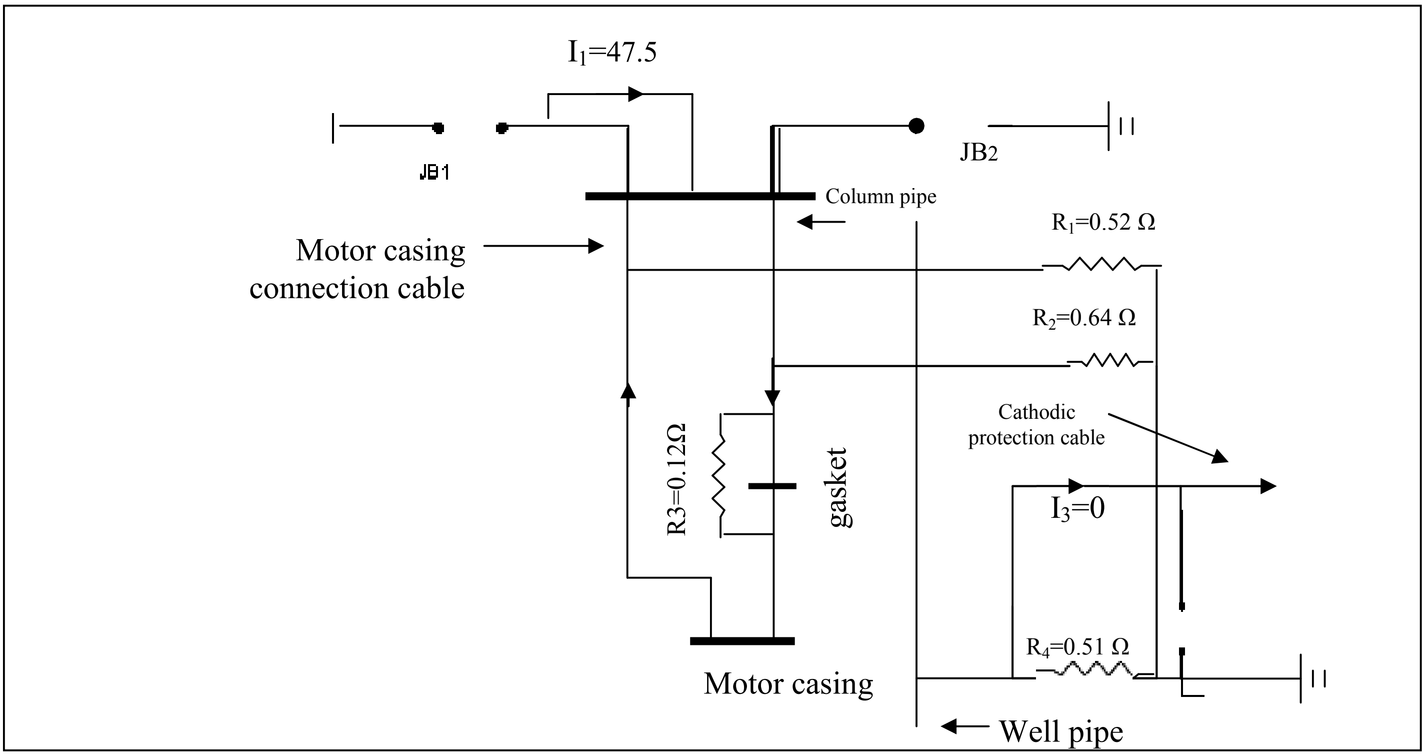

Fig. (8), The grounding cct of test (7)

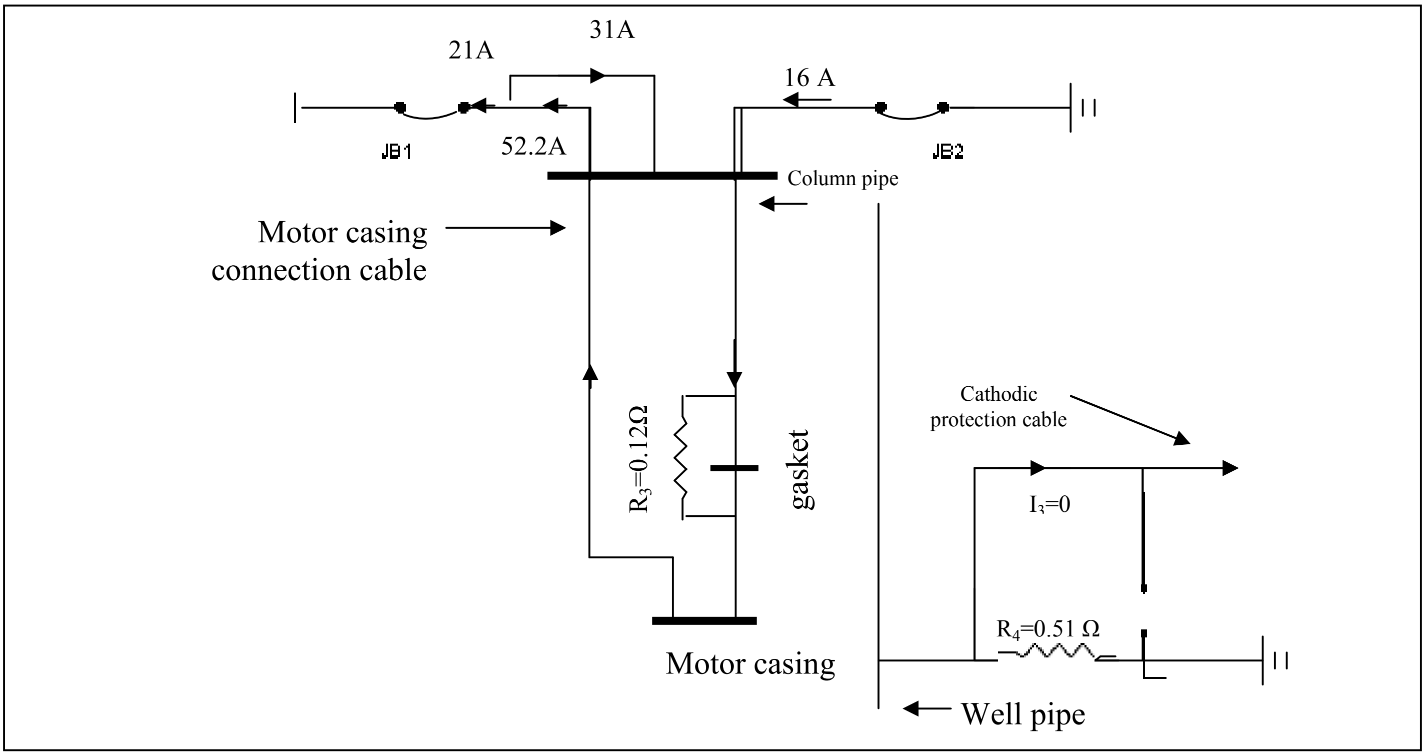

Fig. (9), The grounding cct of test (8)

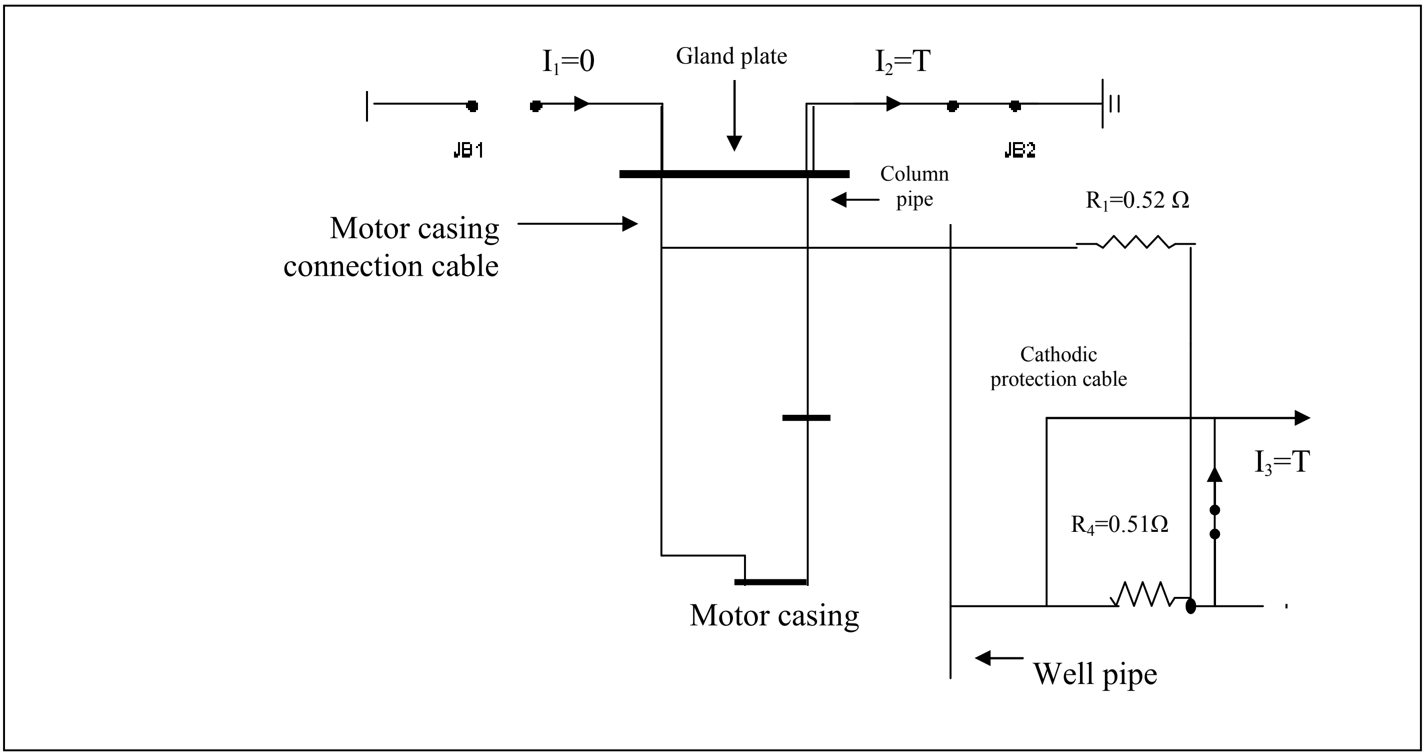

Fig. (10), The grounding cct of test (9)

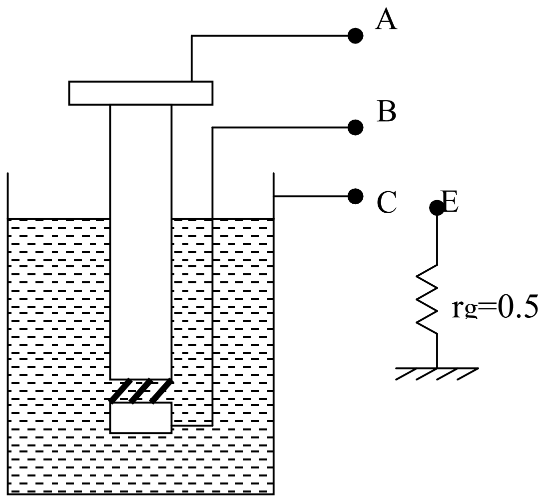

Fig. (11), The original system

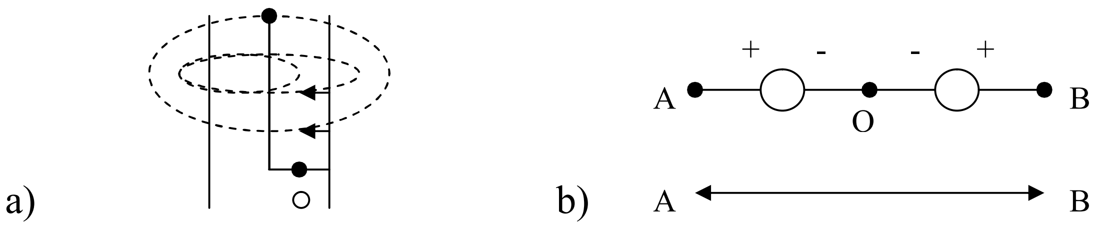

Fig. (12), The flux lines and the polarity of induced voltages

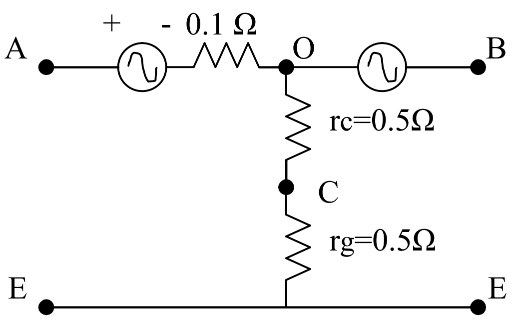

Fig. (13), The simplifying analytic cct of the original system

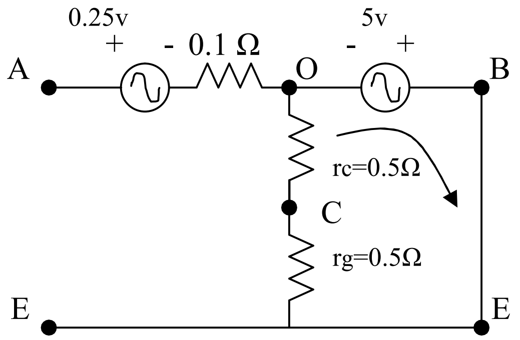

Fig. (14) The corresponding electrical cct of test (2)

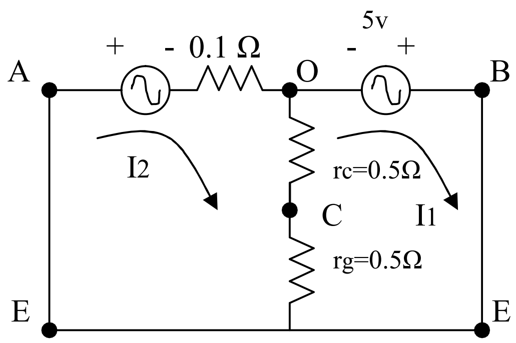

Fig. (15) The corresponding electrical cct of test (3)

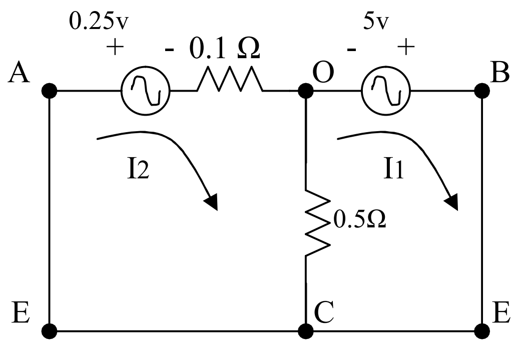

Fig. (16) The corresponding electrical cct of test (4)

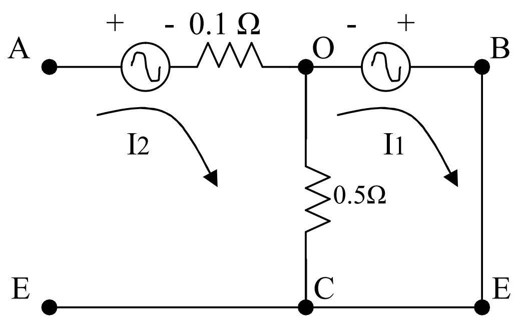

Fig. (17) The corresponding electrical cct of test (5)

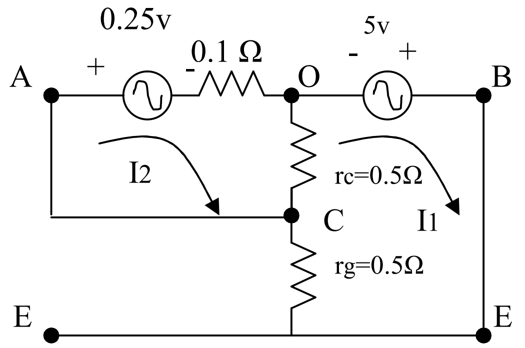

Fig. (18) The corresponding electrical cct of test (6)

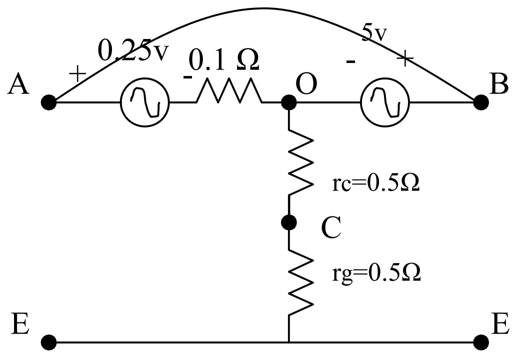

Fig. (19) The corresponding electrical cct of test (7)

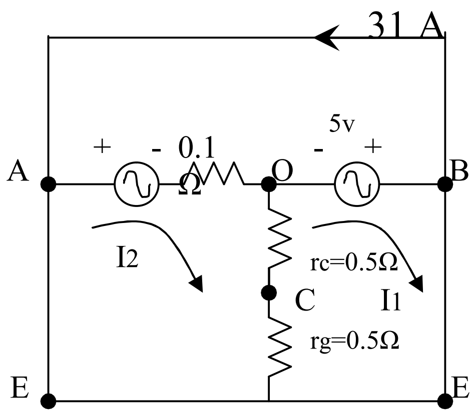

Fig. (20) The corresponding electrical cct of test (8)

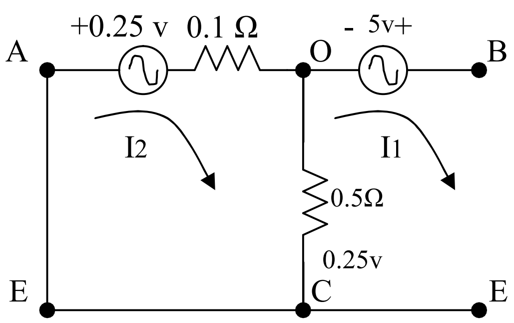

Fig. (21) The corresponding electrical cct of test (9)