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Influence of the Situation of Fault assumed to be Occurred at Various Hypothetical Points of Certain Transmission Line and other Facts on the Fault Current.

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"INFLUENCE OF THE SITUATION OF FAULT ASSUMED TO BE OCCURRED AT VARIOUS HYPOTHETICAL POINTS OF CERTAIN TRANSMISSION LINE AND OTHER FACTORS ON THE FAULT CURRENT."

BY

M. Abd El-Moneim Tantawy and
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ABSTRACT:

This paper presents a new derivation of the effect of connections of the three phase transformer banks and the modes of earthing on the performance of the transmission line in an abnormal condition. This is because the connection of the transformer banks affects the zero sequence network.

From our researches we deduce that the modes of the neutral earthing of the generator (source) and the motor (load) influence the fault current along the transmission line.

1. INTRODUCTION:

Earthing is achieved by electrically connecting the respective parts in the installations to some system of electrical conductors or electrodes placed in intimate contact with the soil some distance below ground level. This contacting assembly is called the earthing. The metallic conductors connecting the parts of the installations with the earthing are called earthing connections.

In electrical installations, the following components must be earthed:

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1- The frames, tanks and enclosures of electric machines, transformers and apparatus, lighting fittings, and other items of equipments.

2- The operating machanisms of tho switchgear.

3- The secondary windings of the instrument transformers.

4- The frameworks of the switchboards, control boards, individual panel boards and cubicles.

5- The structural steel work of indoor and outdoor substations, metal cable jointing boxes, the metal sheaths of the cables, the rigid metal conduit runs, and similar metalwork.

Possible circuits and inst allations should be connected to natural" earthings in the form of nearly underground services r structures such as: water and other piping mains and the steel ork of buildings and other structures having underground contact ith the soil, the lead sheaths of buried cables and other metllic objects in contact with the soil. Methods of earthing ower systems are classified consequently as:

1) Solidly earthed.
2) Earthing through resistance.
3) Earthing through coil.
4) Earthing through condenser.
5) Arc suppression coil.

If the current may be allowed to have several times of the ıll load current by using a low resistance, the loss in the sistance would have many times of the full load of the generor, if an earth fault suddenly developed, the generator shaft d couplings may be damaged and the machine falls out of synchnism. The generally accepted purpose of the reactance type of t e generator neutrals is to limit the earth fault current in t e unsymmetrical faults to have the 3-phase fault current of t e generator.

When the neutral grounding is attained through a reactance, the magnitude of phase to ground voltage depends upon the ratio k ($k = \frac{x_o}{x_1}$), while in the case of resistance grounding the ratio ($\frac{R_o}{x_1}$) controls the rise in voltage on healthy phases.

Because the connection of the transformer banks affects the zero sequence network, we study how their connections have an important effect on the performance of the transmission line at the abnormal conditions.

2- VARIOUS MODES OF CONNECTION OF THE NEUTRAL POINT OF THE GENERATOR AND THE LOAD TO GROUND.

2.a- The neutral point of generator to ground through a certain impedance and that of the load solidly earthed.

2.a.1- The neutral point of the generator solidly earthed.

The network chosen for our research consists of a source, load, step-up, step-down transformere and a transmission line which are connected as displayed in Fig. 1. The convergence of the set of curves representing the fault current versus the localization of fault along the transmission line, when the single line -to- ground fault occurs through ground impedance (N) is pronounced as shown in Fig. 2. In this case it is cleared that, the variation of the connection of the three phase step-up transformer banks does not influence effectively the value of the fault current along the transmission line. When the single line -to- ground fault occurs through ground impedance, the series curve (N) converges with a rate more than that of the case of zero impedance (M). This means that at any point along the transmission line, and moving vertically, the fault current does not

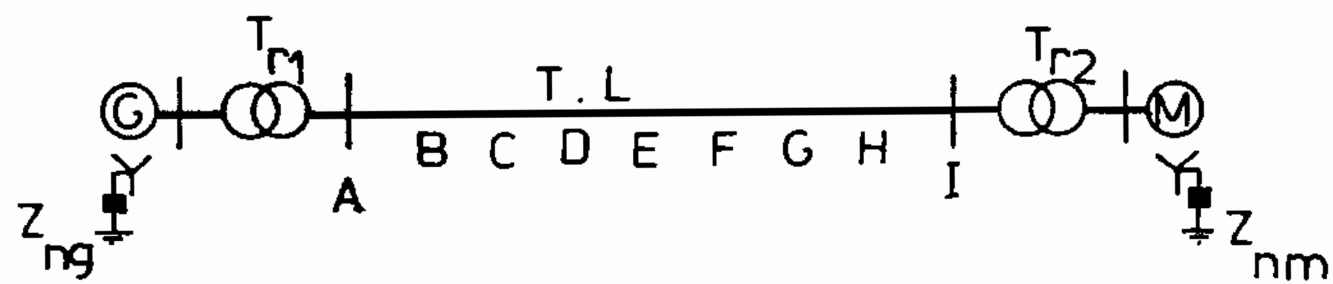


FIG.(1) TWO MACHINE SYSTEM.

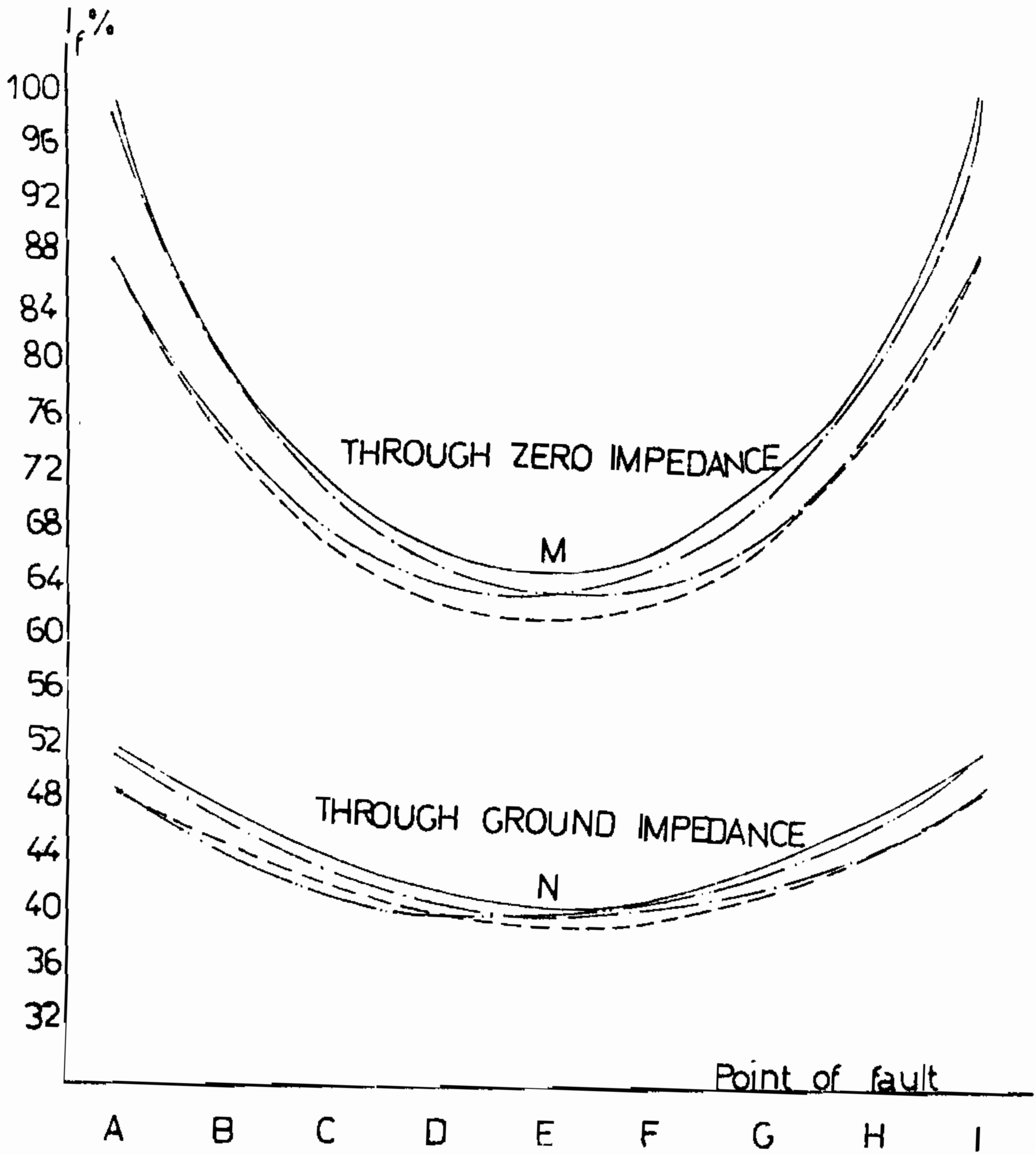
THE RATING OF EACH MOTOR AND GENERATOR ARE:-

125 M.V.A - 600 V - $X_1 = X_2 = 10\%$ AND $X_0 = 4\%$

T_1 - T_2 125 M.V.A-600/4160 VOLTS AND X = 5%

THE CONDITIONS OF THE LINE ARE:-

$X_1 = X_2 = 15\%$ - $X_0 = 50\%$. $Z_g = 10$ OHMS.



I_f %
100
96
92
88
84
80
76
72
68
64
60
56
52
48
44
40
36
32
THROUGH ZERO IMPEDANCE
M
THROUGH GROUND IMPEDANCE
N
Point of fault
A
B
C
D
E
F
G
H
I

FIG. (2)

____ BOTH STEP-UP AND STEP DOWN TRAN-
CONNECTED (Y_G/Δ) THROUGH ZEPO IMPE-
DANCE OR THROUGH Z_G.

---- BOTH STEP-UP AND STEP-DOWN TRAN-
CONNECTED (Y_G/Y_G) THROUGH ZERO IMPED-
ANCE OR THROUGH Z_G

—.— STEP-UP TRAN(Δ/Y_G) AND STEP-DOWN TRAN
CONNECTED (Y/Y_G) THROUGH ZERO IMPEDA-
NCE OR THROUGH Z_G.

—..— STEP-UP TRAN. CONNECTED (Y/Y_G) AND
STEP-DOWN TRAN. CONNECTED (Δ/Y_G) THR-
OUGH ZERO IMPEDANCE OR THROUGH Z_G

vary with a considerable value i.e. it is independent of the modes of connections of the transformer banks.

When the step-up and step-down transformers are connected Delta/Star earthed, the value of the fault current has greater values than any other connections, that is because the grounding impedance of the generator and the load does not appear in the zero-sequence network and therefore the zero-sequence impendance has a limited value i.e. does not affect the fault current.

When the step-up and step-down transformers are connected star earthed/star earthed, the zero-sequence impedance is accommodated, and therefore the zero-sequence impedance of the network becomes higher than any other connections and the fault current is less.

I_{f_1} is the fault current when the single line -to-ground fault occurs through zero impedance.

I_{f_2} is the fault current when the single line -to-ground fault occurs through ground impedance.

2.a.2- The neutral point of generator earthed through an impedance of 5% (say)

The influence of the ground impedance of the generator to have more divergence in this case, becomes more pronounced than the effect in the case of choosing the grounding impedance of the generator to have lower value than 5%.

This influence is to lower the fault current percentage at the points near the generator only as revealed in Fig. 3. Noticing that this reduction occurs in the case of connecting both transformers (Star earthed/star earthed), and also the case of the connections (Star earthed/star earthed) for step-up, and

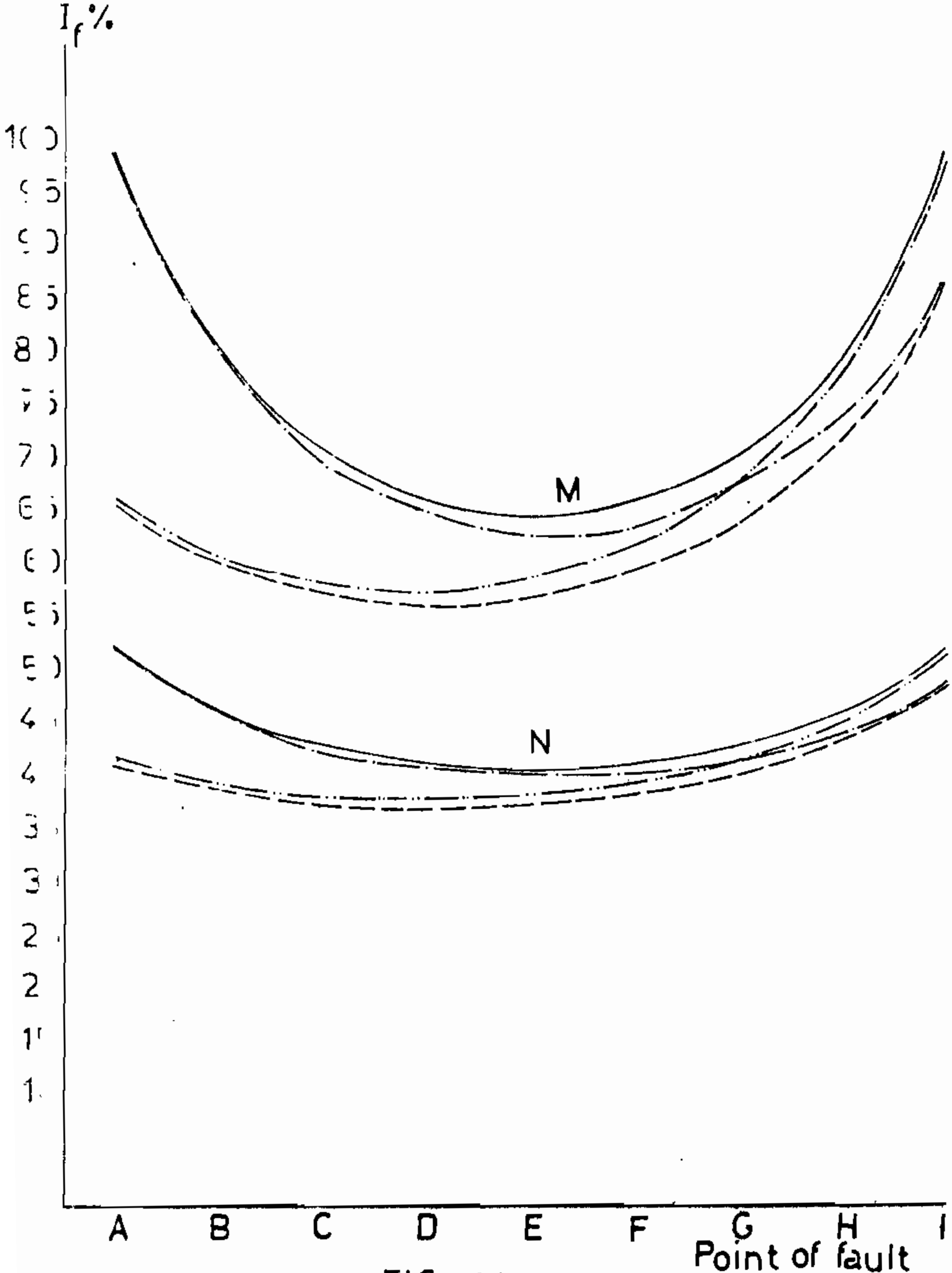


FIG. (3)

(Delta/star earthed) for step-down transformer. This is due to the increasing the total zero-sequence impedance owing to the higher value of the grounding impedance.

Finally, the preceding phenomenon is repeated for both manners of occuring the fault through or not through the grounding impedance.

2.b- <u>Connection of the neutral point of the load to ground through an impendance of 5% and that of the generator earthed through a certain impedance.</u>

2.b.1- The neutral point of the generator solidly earthed.

The set of curves which represents the operation of the transmission line in the abnormal condition (single line -to-ground fault) is the inverse of the curves which are debated in the prementioned section. This owing to grounding the neutral point of the load through a certain impedance while in the case (2.c), the neutral of the generator is earthed through the same impedance as shown in Fig. 4. This divergence and convergence are existed between the different characteristics for each case of occurring thefault through or not through a grounding impedance. In this case, the divergence occurs at point I near the load, and the convergence is remarked at the point A near the generator.

2.b.2- The neutral point of the generator earthed through an impedance of 5%.

In this case, the divergence occurs at the point A near the generator in a similar way as that of the point I near the motor as revealed in Fig. 5.

When each step-up and the step-down transformers are

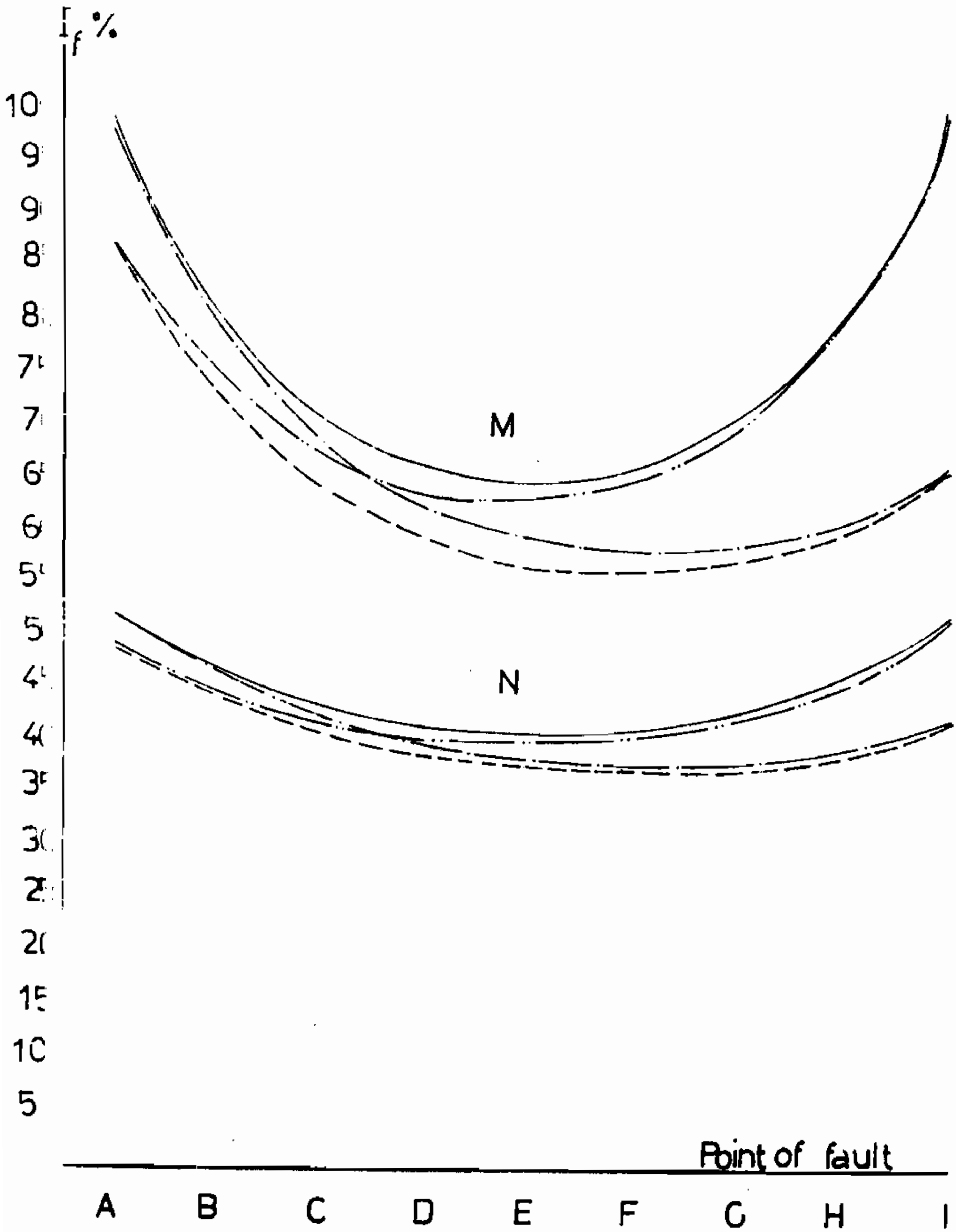
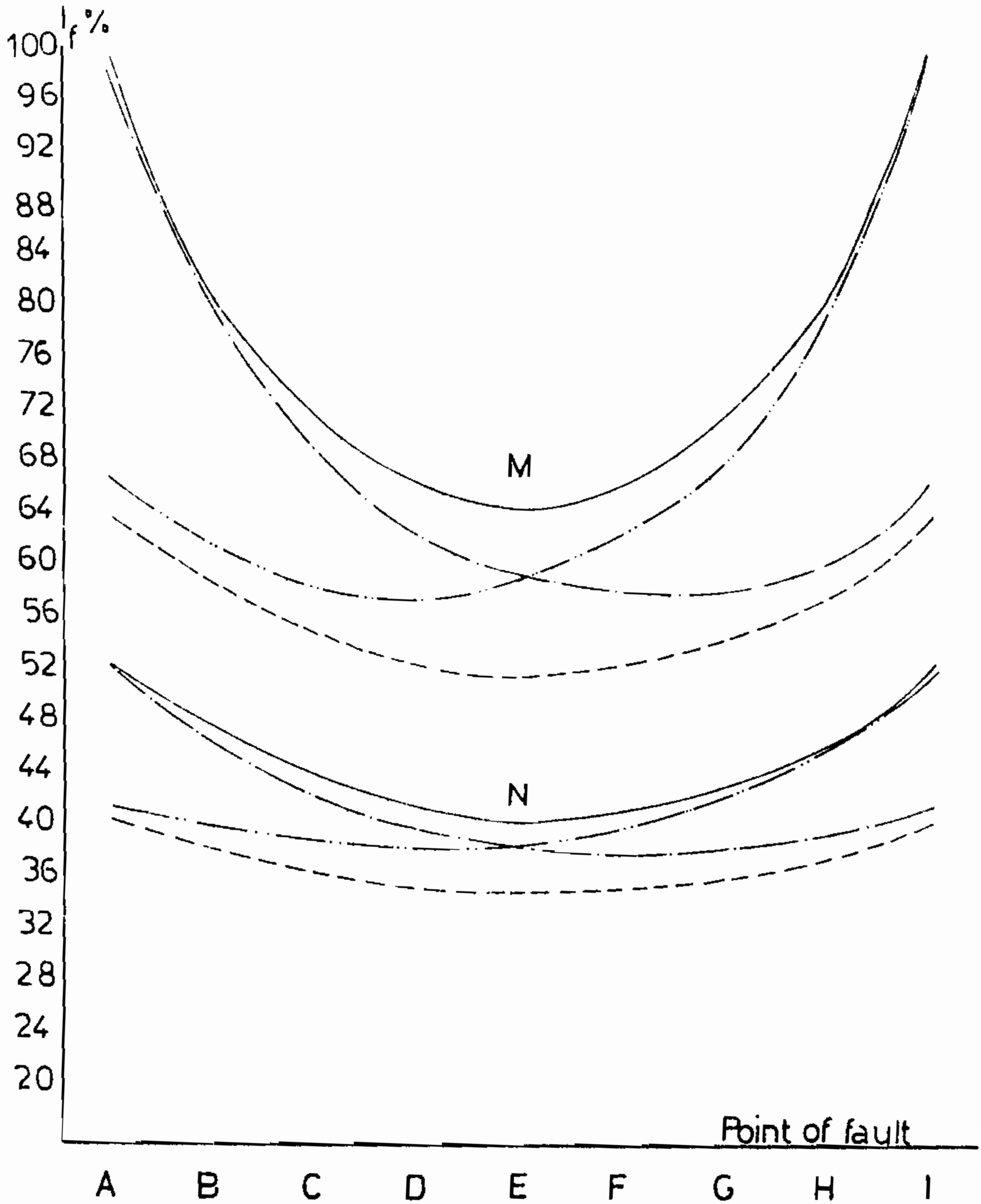


FIG. (4)


I_f %
100
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92
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84
80
76
72
68
64
60
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52
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44
40
36
32
28
24
20
M
N
Point of fault
A
B
C
D
E
F
G
H
I

FIG. (5)

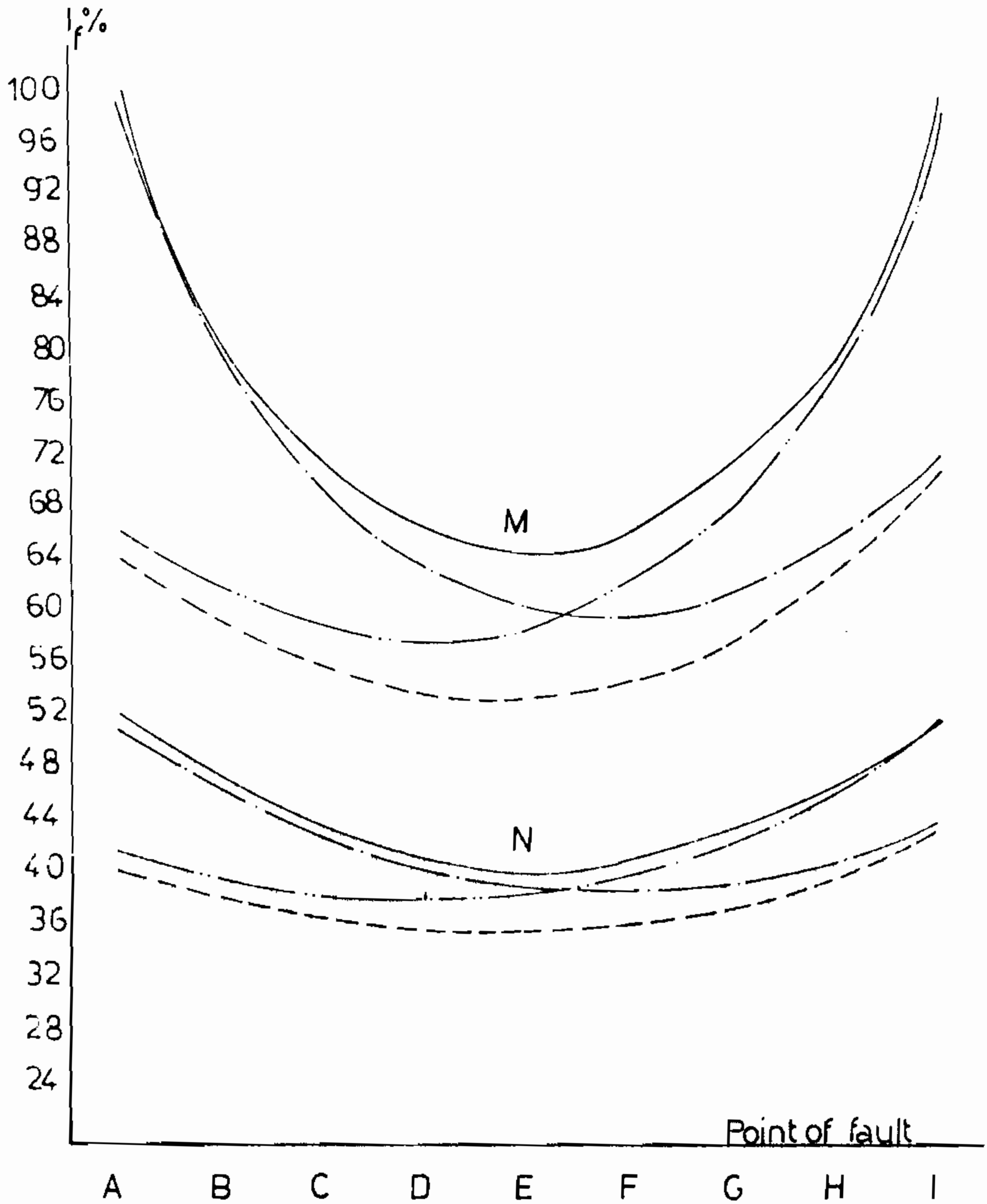
:onnected delta/star earthed or star earthed/star earthed, the :ault current at the point E in the middle of the transmission .ine divides each curve into 2 symmetrical parts. The curves which represent the fault current when the step-up transformer .s connected (Delta/star earthed) and the step-down is connected Star earthed/star earthed), or the inverse, are intersected at he middle of the length of the transmission line i.e. the fault urrent has the same percentage at this point independent of the entioned transformers connections.

2.c- Connection the neutral point of the generator to ground through an impedance of 5% and that of tho load through an impedance of 3%.

The curves group in this case is the inverse to the set of urves in case of having the grounding impedance of the genera- or to be 3% and that of the load equals 5%.

In our case, the divergence at the point A is greater than iat at the point (I) near the load because the grounding imped- ace of the generator is greater than that of the load as disp- ayed in Fig. 6.

The divergence between the members of one series of curves ikes place also along the other points along the transmission ne located between the generator and the load. On studying e case of connecting the step-up transformer (Delta/Star ear- ed) and the step-down transformer (Star earthed/star earthed), e grounding impedance of the generator does not affect the ult current. On the other hand, if the step-up transformer is nnected (star earthed/Star earthed), and the step-down trans- rmer is connected (Delta/Star earthed), the grounding imped- ce of the load has no effect on the fault current.


I_f%
100
96
92
88
84
80
76
72
68
64
60
56
52
48
44
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32
28
24
M
N
Point of fault
A
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FIG. (6)

2.d- Different patterns of isolating the neutral point of generator and load.

2.d.1- Both the neutral point of the generator and that of the load isolated from the ground.

When both step-up and step-down transformers are connected (star earthed/star earthed), we obtain an important result that is no return path to the zero sequence current and therefore there is no return path to the fault current.

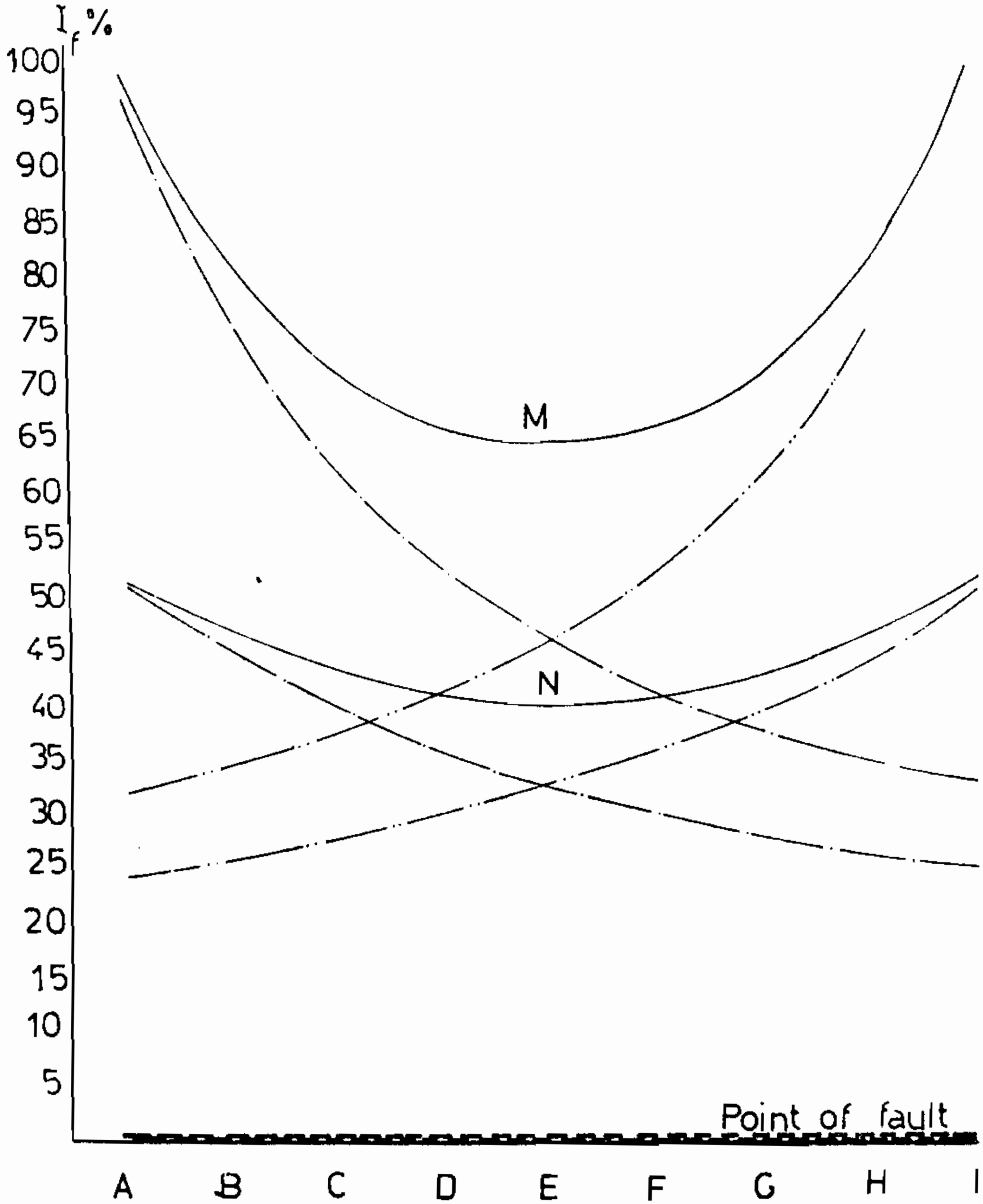
The fault current along the transmission line equals zero, then the curve of the fault current locate on the horizontal axis, as revealed in Fig. 7.

When the step-up transformer is connected (Delta/star earthed), and the step-down transformer is connected (Star earthed/star earthed), the curve in this case converges at the point (A) and takes to diverge when the fault position to be moved from point (A) to point(I). When the step-up transformer is connected (Delta/star earthed) and the step-down transformer is connected (Star earthed/star earthed) or the inverse, the fault current at point (E) is the same in the prementioned cases.

2.d.2- Connection of the neutral point of the generator to ground through an impedance of 3%, and that of the load isolated from the ground.

If the step-down transformer is connected (Star earthed/ star earthed), the curves of fault current against the fault position along the transmission line, have not a rising part towards the load as revealed in Fig. 8.

When the step-up transformer is connected (Delta/star earthed), the grounding impedance of the generator does not appear in the zero sequence network, and therefore when the



I_f %
100
95
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75
70
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Point of fault
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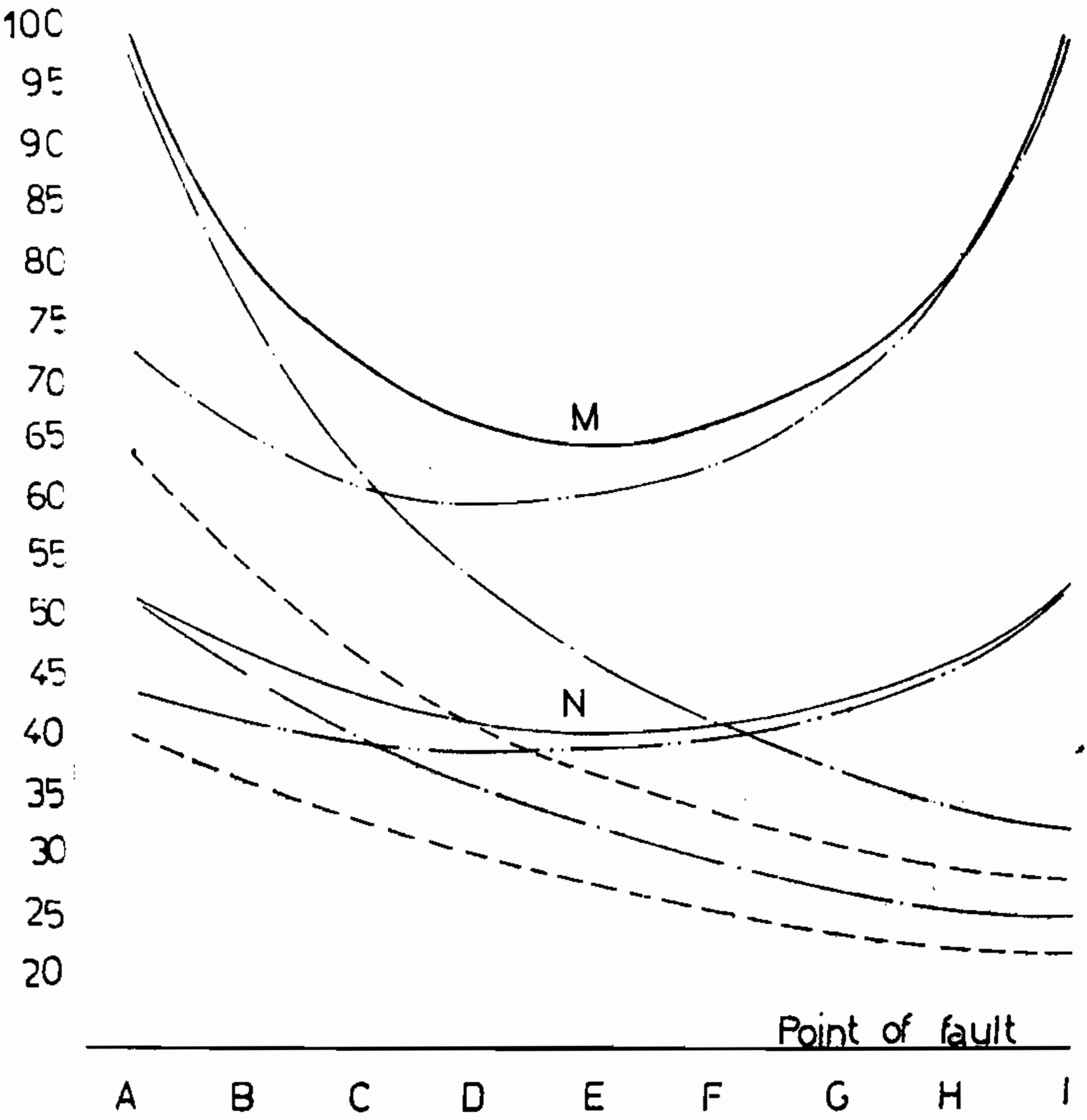
FIG. (7)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Point of fault
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H
I

FIG. (8)

neutral point of the generator is isloating, this does not affect the performance of the transmission line.

2.d.3- Connection of the neutral point of the load to ground through an impedance of 5% and that of the generator isolating from the ground.

When the step-up transformer is connected (star earthed/ star earthed), the curves are deviated at the point (A) near the supply and converges at point (I) near the load as shown in Fig. 9.

2.e- Assessment of the localization of the minimum of the fault current for various grounding impedance of generator and load.

In the circuit whose single line diagram is revealed in Fig. 10., we assume that a single-line -to- ground fault occurring at point (F) on the transmission line. From this figure, the values of the positive, the negative and the zero sequence impedance are

$$Z_1 = Z_2 = 0.05\ (2 + x_1 L - x^2/L^2)$$

where L is the length of the transmission line.

and :

$$Z_o = \frac{(0.09 + Z_{1N} + 0.5\ x/L)(0.59 + Z_{2N} - 0.5\ x/L)}{0.68 + Z_{1N} + Z_{2N}}$$

Since $I_f = \dfrac{3\ E}{Z_1 + Z_2 + Z_o}$

and therefore:

(I) At $Z_{1N} = Z_{2N} = 0$

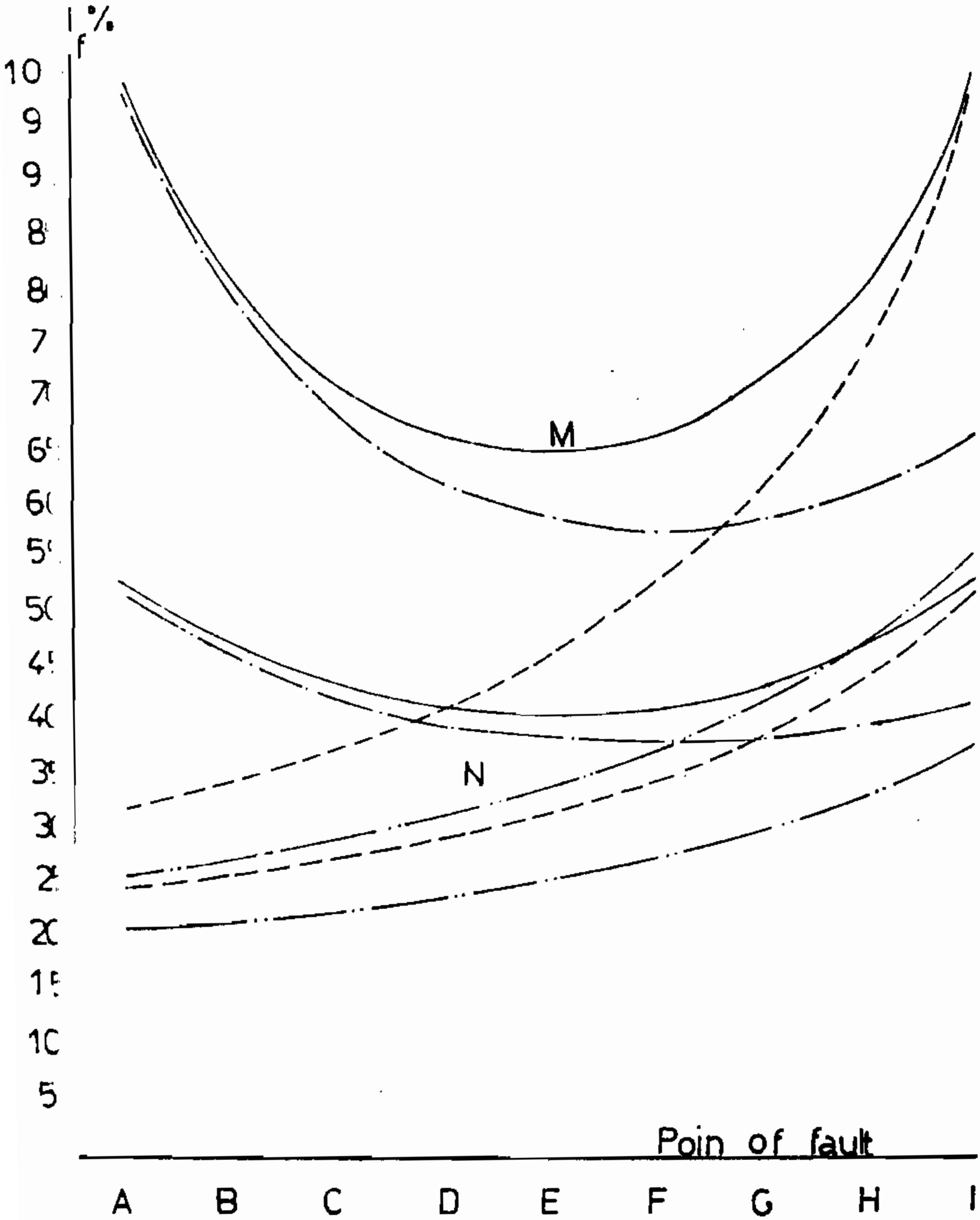

FIG (9)

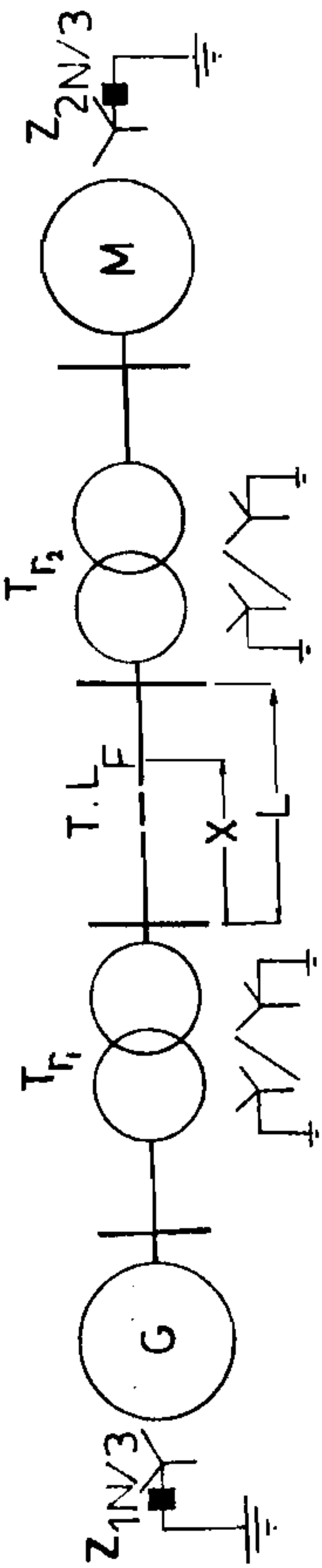

FIG.(10)

$$I_f = \frac{3 \times 0.68}{0.068(2 + x/L - x^2/L^2) + (0.09 + 0.5\ x/L)(0.59 - 0.5\ x/L)}$$

The fault current becomes minimum at:

$$\frac{d\ I_f}{d\ x} = 0 \text{ i.e. } \quad 0.318 = 2 \times 0.319\ x/L$$

$$\text{i.e. } x = L/2$$

(II) At $Z_{1N}/3 = 3\%$, $Z_{2N}/3 = 0$

$$I_f = \frac{3 \times 0.77}{0.077(2 + x/L - x^2/L^2) + (0.1062 + 0.205\ x/L - 0.25\ x^2/L^2)}$$

The fault current is a minimum at:

$$0.282 = 0.654 \quad x/L$$

$$x = 0.4312\ L$$

(III) At $Z_{1N}/3 = 5\%$, $Z_{2N} = 0$

In this case:

$$I_f = \frac{3 \times 0.83}{0.083(2 + x/L - x^2/L^2) + (0.24 + 0.5\ x/L)(0.59 - 0.5\ x/L)}$$

The fault current is a minimum at:

$$x = 0.387\ L$$

(IV) At $Z_{1N}\% = 15\%$, $Z_{2N}\% = 9\%$

In this case:

$$I_f = \frac{3 \times 0.92}{0.092(2 + x/L - x^2/L^2)+(0.24 + 0.5\ x/L)(0.68 - 0.5\ x/L)}$$

The fault current is a minimum at:

$x = 0.456\ L$

(V) At $Z_{1N} = 0$, $Z_{2N}\% = 15\%$.

$$I_f = \frac{3 \times 0.83}{0.083(2 + x/L - x^2/L^2)+(0.09 + 0.5\ x/L)(0.74 - 0.5\ x/L)}$$

The fault current is a minimum at:

$x = 0.6126\ L$

(VI) At $Z_{1N}\% = 9\%$, $Z_{2N}\% = 15\%$.

$$I_f = \frac{3 \times 0.92}{0.092(2 + x/L - x^2/L^2)+(0.18 + 0.5\ x/L)(0.74 - 0.5\ x/L)}$$

The fault current is a minimum at:

$x = 0.5439\ L$

(VII) At $Z_{1N} = Z_{2N} = 15\%$

$$I_f = \frac{3 \times 0.98}{0.098(2 + x/L - x^2/L^2)+(0.24 + 0.5\ x/L)(0.74 - 0.5\ x/L)}$$

The fault current becomes a minimum at:

$x = 0.5\ L$

3. CONCLUSIONS:

When the grounding impe dance of the generator equals to that of the motor, the fault current becomes minimum at the middle of the length of the transmission line.

If the grounding impendance of the generator is to be increased than that of the motor, the position of the minimum of the fault current moves in the direction of the generator, and the inverse is correct. This is true for the (star earthed /star earthed) step-up and step-down transformers, the case of which we have minimum curve when the fault occurs through zero impedance.

When the neutral point of the generator is isolated, the fault current has a minimum value at the point (A) (near the generator), if the neutral point of the motor is isolated, the fault becomes minimum at point (I) near the motor. In the case of isolating both the neutral point of the generator, and that of the motor, the fault current equals zero along the transmission line.

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