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CONTROL OF HVDC BRIDGES UNDER LIGHT LOAD CONDITIONS

BY

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ABSTRACT:

The performance of a HVDC transmission system under light load conditions is investigated. Two types of control schemes are used, namely constant igintion delay and constant power factor. The study has been carried out as a digital simulation. An algorithm is designed to arrive at the results. It has been shown that a reactive power is needed to reduce the over voltages induced across the bridges. This reactive power requires more switching operation in case of ignition delay angle however smaller in magnitude than in case of power factor angle. It has been advised that for relability of operations, the power factor control scheme is preferable.

INTRODUCTION:

The control system of a HVDC transmission is avery important part of the whole structure. In fact, many of the operational properties are determined by the control system. The functional requirements of any control may be summed up to [1,2,3] ;

1) Sufficient stability margins and speed of response,
2) Less affected by abnormal harmonics generated by the converters,
3) Correct rectifier and inverter operation at frequency variations,
4) Fewest possible commutation failures on inverter side,

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5) Operation with smallest possible ignition delay angle and extinction angle without risk for commutation failure (these angles directly affects the reactive power consumption),

6) Fast recovery after a major transient.

These requirements are hard to satisfy simultanously. Most research work is directed towards the study of full load conditions, [4, 5]. However, under light load conditions, the operation may be in trouble. The reactive power produced by the shunt capacitance of the Hvac lines exceeds that consumed by the series inductance of the lines and transformers. This leads to undesirably high voltage at and near a rectifier station. Consequently mal-operation of DC bridges occurs.

In order to avoid mis-operation of the valves, one must limit the maximum value of the jump voltage and the peak inverse voltage across valves to values satisfy the design requirements of the valves. Therefore overvaltoges should be adjusted automatically by switching in reactive power corrective devices.

In this paper a detailed study is done to arrive at the capacity of the reactive compensations as well as the manner in which it should be added.

Prevalent full load requirements:

A two terminal HVDC Transmission, the data of which are in [6] is used for this study. Some of the basic data are:

reactance of the converter transformer	= 0.2 p.u.
induced voltage of transformer	= 1.0 p.u.
direct voltage at rated power	= 1.12p.u.
commutation overlap	$u = 25^\circ$
ignition delay angle	$\alpha = 15^\circ$
transformer tap on rectifier side	= 1.0

with this information the theoretical jump voltage at extinction of the arc is

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$$V_{je} = \sqrt{2}\ E_o \sin(\alpha + u)$$
$$= 0.9090394 \quad p.u \qquad ....(1)$$

and the peak inverse voltage

$$P.I.V = 1.047\ Vdo$$
$$= 1.4112457 \quad p.u. \qquad ....(2)$$

The ratio;

$$\frac{Vd}{Vd_o} = 0.8296296 \qquad ....(3)$$

Light Load Conditions:

Under light load conditions on ac transmission, undesirable high voltage appears at the converter stations. This situation is further aggravated when the rectifier also in operating at light load because then the reactive power consumed by it is less than that produced by its harmonic filters [7] . On way to alleviate this problem is to make the rectifier consumes additional reactive power. How this can be done is the main concern of this study. Two types of control are considered; the ignition delay angle control and the constant power factor control [3] .

Case 1: Ignition delay angle control

The rectifier is forced to consume additional reactive power by increasing its ignition angle;

$Q = P_a \left(\frac{\cos\alpha + \cos(\alpha + u)}{2}\right)$. This remedy is subject to the limitation that the peak inverse as well as the jump voltages across valves do not exceed their respective values at full load. To overcome this conflict, additional reactive power is needed. To compute the values as well as the switching policy of this power, a computer routine is tailored. Aflow chart(1) of which is shown.

Results of this study are summerized in Figures 1,2,3 & 4. These results has been obtained under the assumption of stable operating conditions and the delay in the control action is ignored. It is constructive to note the variation of reactive power with load. Note also that with operation near full load no reactive power is needed.

Case 2: Power factor control scheme

Calculations are processed under the same conditions. However, a modification in the computing scheme is required. This is shown in Flow chart (2). The power factor angle is set at 23°.

The results are summerized and depicted graphically in Figures 5,6,7, 8 & 9. It should be observed that the values of over voltages associated with this type of control is more lower than with ignition delay control. Therefore this type of control provides more protection for converters under light load circumstances. On the other hand, the capacity of the reactive station is higher compared with that required in Case (1). However, the switching transients are now more less due to the few number of steps where the reactive power is switched at.

Conclusions:

Reactive power is required for converter protection under light conditions. It can be obtained by switching reactive stations. Under ignition delay angle on the rectifier side the required reactive power is lower than in case of power factor control. However, the switching operation may be a crucial draw back. The study also show that under power factor control, large ignition delays under light load conditions and consequently at disturbances can be easily achieved without risk of overvaltages. Thus reducing commutation failure. Commutation failure analysis will be reported upon completion.

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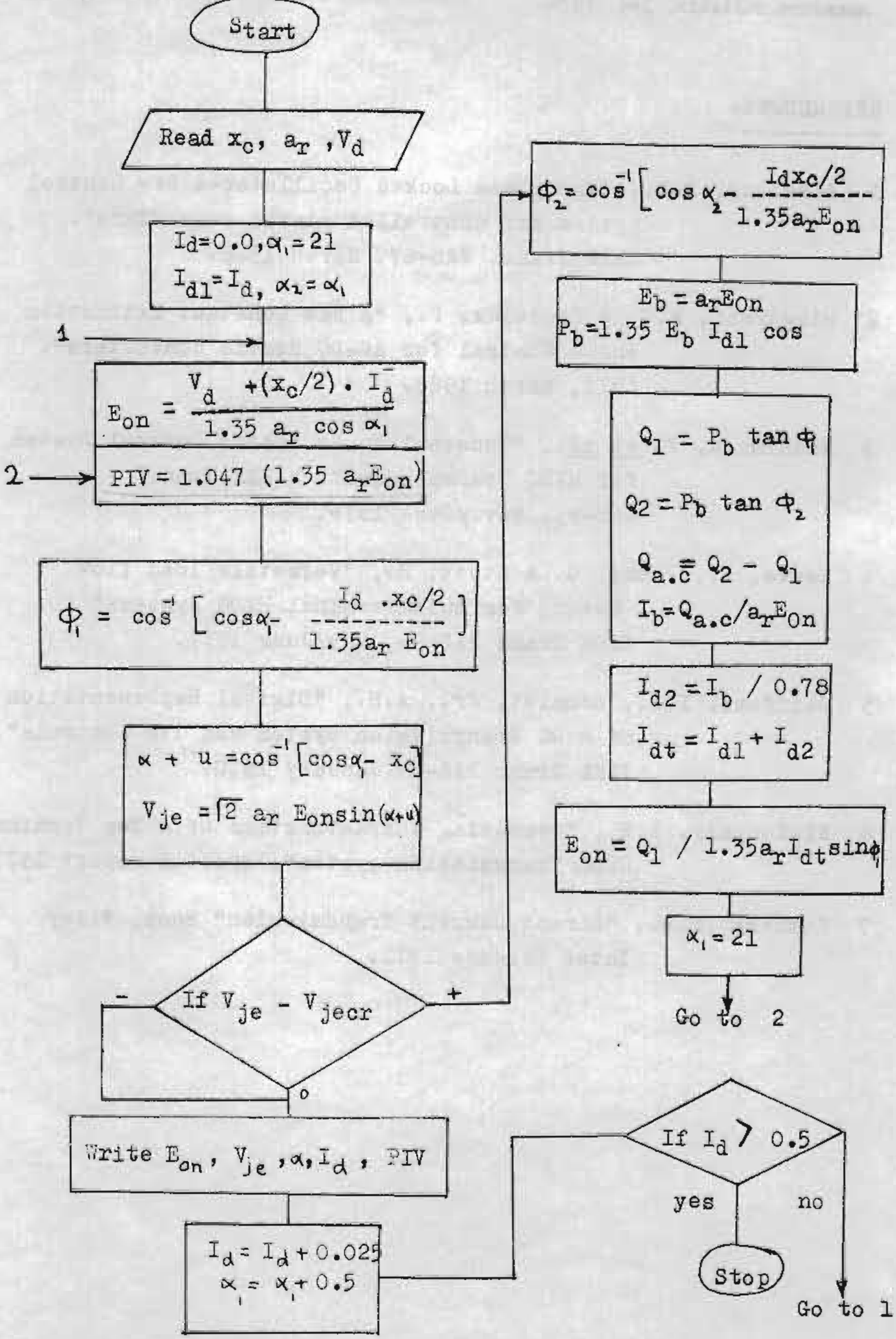

Start
Read xc, ar ,Vd
Id=0.0, α1 = 21
Id1 = Id, α2 = α1
1
Eon = (Vd + (xc/2) . Id) / (1.35 ar cos α1)
2
PIV = 1.047 (1.35 arEon)
φ1 = cos-1 [cosα1 - Id .xc/2 / 1.35ar Eon]
α + u = cos-1 [cosα1 - xc]
Vje = √2 ar Eon sin(α+u)
If Vje - Vjecr
-
+
o
Write Eon, Vje, α, Id, PIV
Id = Id + 0.025
α1 = α1 + 0.5
φ2 = cos-1 [cos α2 - Idxc/2 / 1.35arEon
Eb = arEon
Pb = 1.35 Eb Id1 cos
Q1 = Pb tan φ1
Q2 = Pb tan φ2
Qa.c = Q2 - Q1
Ib = Qa.c/arEon
Id2 = Ib / 0.78
Idt = Id1 + Id2
Eon = Q1 / 1.35arIdtsinφ1
α1 = 21
Go to 2
If Id > 0.5
yes
no
Stop
Go to 1

Flow chart (1)

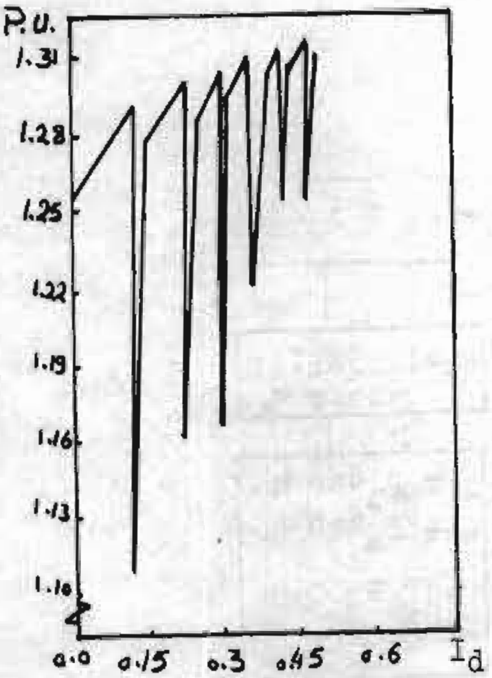


Fig.(1) Peak inverse voltage vs. direct current.

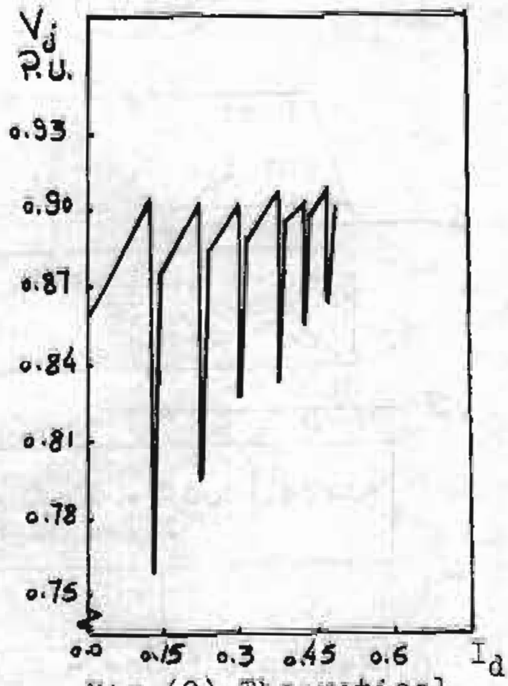


Fig.(2) Theoretical jump voltage vs. direct current.

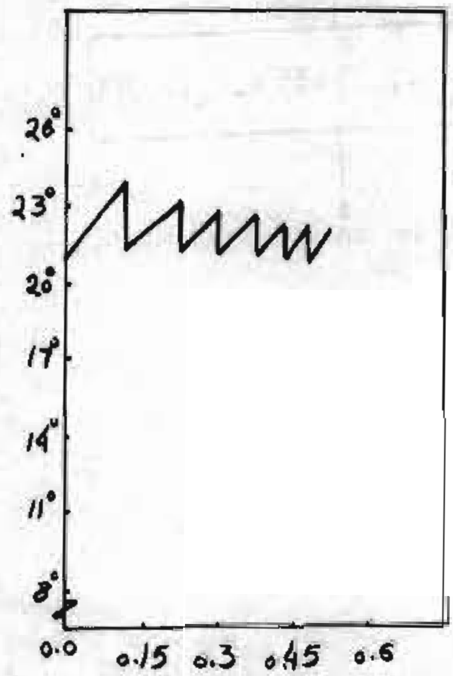


Fig.(3) Ignition delay angle vs. direct current

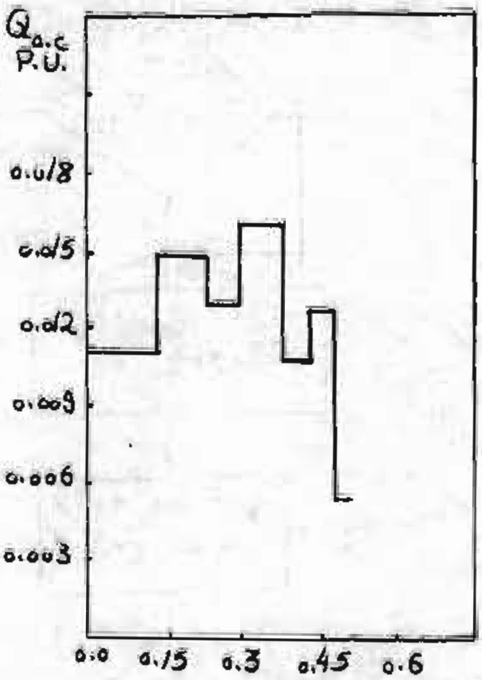
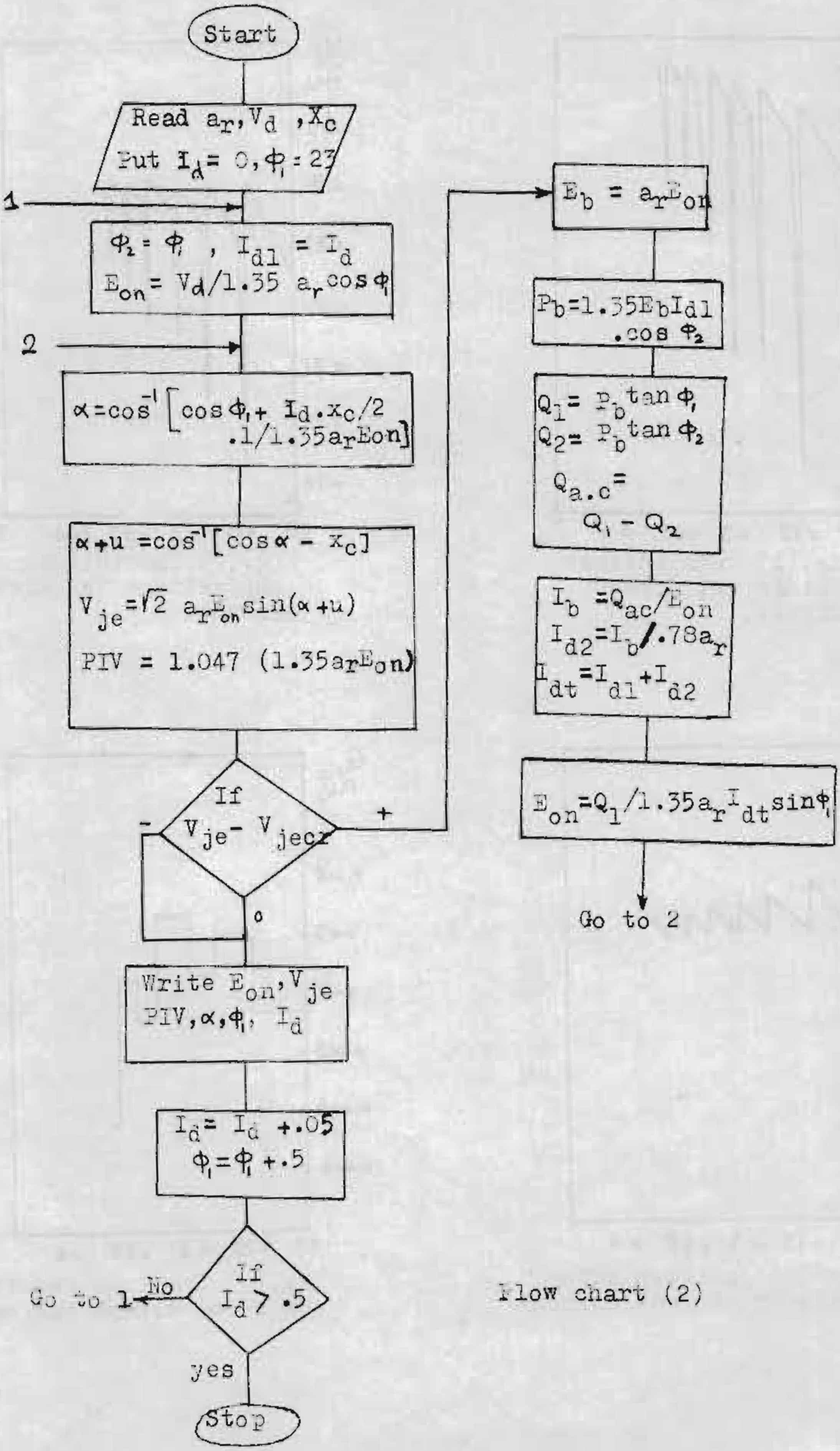


Fig.(4) Required reactive power vs. direct current


Start
Read ar, Vd, Xc
Put Id = 0, φ1 = 23
1
φ2 = φ1, Id1 = Id
Eon = Vd/1.35 ar cos φ1
2
α = cos⁻¹ [cos φ1 + Id.xc/2 .1/1.35arEon]
α + u = cos⁻¹ [cos α − xc]
Vje = √2 arEon sin(α + u)
PIV = 1.047 (1.35arEon)
If Vje − Vjecr
−
+
0
Write Eon, Vje
PIV, α, φ1, Id
Id = Id + .05
φ1 = φ1 + .5
If Id > .5
No
Go to 1
yes
Stop
Eb = arEon
Pb = 1.35EbId1 .cos φ2
Q1 = Pb tan φ1
Q2 = Pb tan φ2
Qa.c = Q1 − Q2
Ib = Qac/Eon
Id2 = Ib/.78ar
Idt = Id1 + Id2
Eon = Q1/1.35arIdt sinφ1
Go to 2

Flow chart (2)

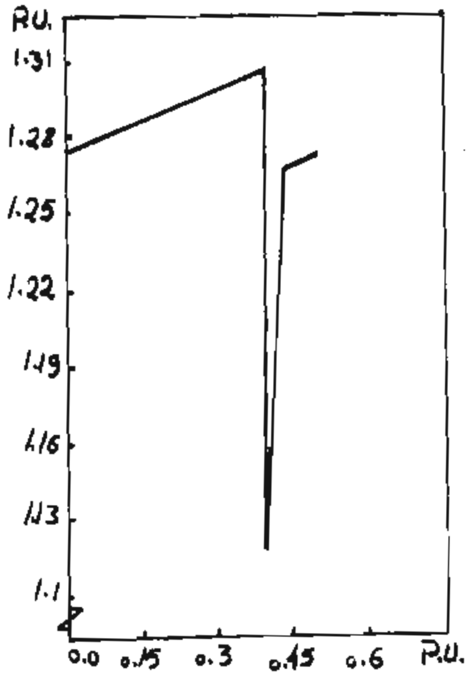


Fig.(5) Peak inverse voltage vs. direct current.

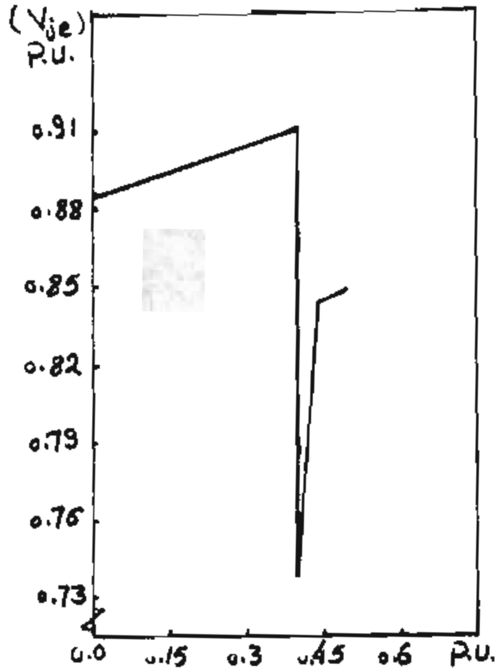


Fig.(6) Theoretical jump voltage vs. direct current.

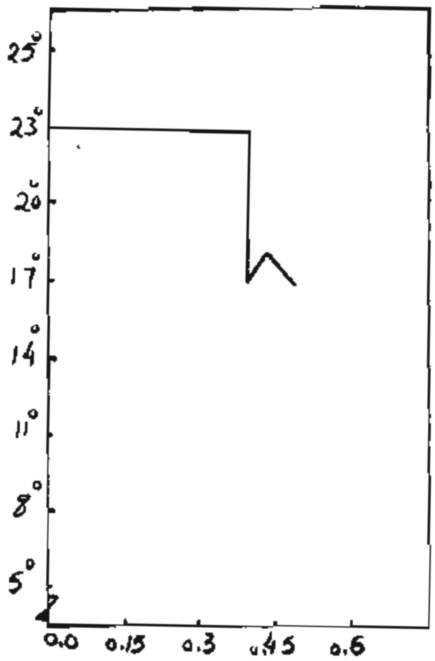


Fig.(7) Ignition delay angle vs. direct current.

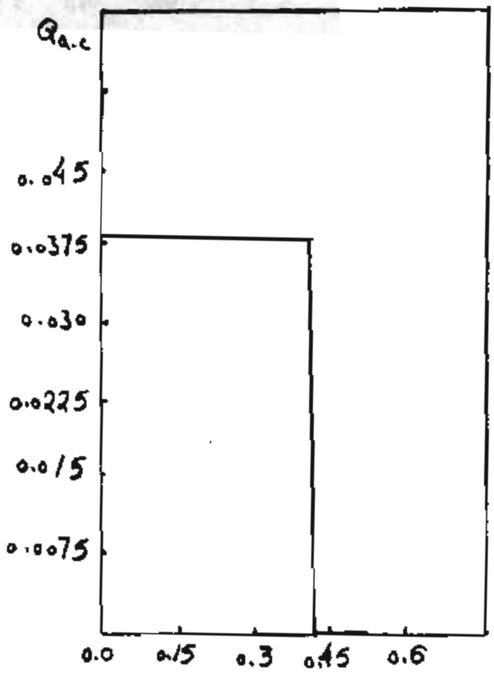


Fig.(8) Required reactive power vs. direct current.

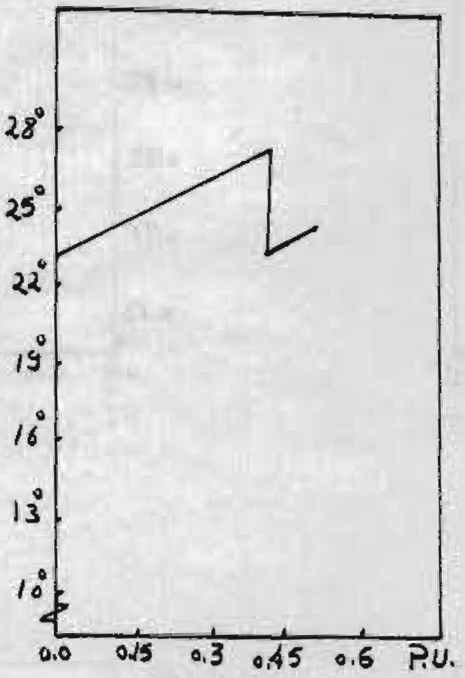


Fig.(9) Power factor angle vs. direct current.