SLOW BANK SYSTEM OF SINP-TOKAMAK: A SHORT REPORT

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Abstract

SINP Tokamak was made operational in July, 1987. The power supply system of the tokamak at that time was designed for a plasma duration of around 2 ms for a peak plasma current of 75 kA. Efforts were directed to increase this duration to 20 ms with the help of a slow bank system designed to work in conjunction with the original fast bank system. The design aspects of the system were completed and the system has been partially executed [1].

Subsequent to this partial implementation, efforts were directed to incorporate the necessary control system and interface facilities between the existing fast bank and the developed slow bank systems. The significant features of the control circuits are that they work according to a well thought out sequences of logic and are designed to guard against possible failures in the existing or the developed power supplies. Efforts have been put to make the operation of the system as much user-friendly as could be worked out within certain practical constraints. The control circuit and interface facilities have been put to extensive tests and are found to work satisfactorily. The entire power supply system is now in active use for different research programmes in the group.

1. Implementation of Slow Bank System for SINP-Tokamak, R. Ray et.al, Saha Centenary Symposium and 8th National Symposium on Plasma Science & Technology, Allahabad, October 11-14, 1993.

Introduction :

A programme was undertaken to extend the plasma duration from around 2 ms to 20 ms by adding a second bank of capacitor to the existing bank. This bank has a separate power supply system for charging but this bank discharges through the same set of ignitron switches.

This second bank has been named

<u>Slow Bank System</u>

Basic Idea :

Both the fast and slow banks are separately charged from two different power supplies. Both the banks are kept isolated through an appropriate diode stacks.

Charging pattern is decided by the well known equation

$$L\frac{di}{dt} + Ri + \frac{\int idt}{C} = E \; ..... \; (1)$$

where E is source voltage for charging.

During discharge, the controlling equation is

$$L\frac{di}{dt} + Ri + \frac{1}{C}\int idt = 0$$

Three solutions are possible for three sets of conditions.

i) $\frac{R^2}{4L^2} > \frac{1}{LC}$

ii) $\frac{R^2}{4L^2} = \frac{1}{LC}$

iii) $\frac{R^2}{4L^2} < \frac{1}{LC}$

cases (i) & (ii) are non-oscillatory and case (iii) is oscillatory.

Solution for non-oscillatory cases (i)

$$i = \frac{-Q_o}{\sqrt{(R^2C^2 - 4LC)}}\left[e^{(-a+b)t} - e^{(-a-b)t}\right]$$

and

$$q = Q_o\left[\frac{RC + \sqrt{(R^2C^2 - 4LC)}}{2\sqrt{(R^2C^2 - 4LC)}}e^{(-a+b)t} - \frac{RC - \sqrt{(R^2C^2 - 4LC)}}{2\sqrt{(R^2C^2 - 4LC)}}e^{(-a-b)t}\right]$$

where $a = \frac{R}{2L}$ and

$$b = \sqrt{\left[\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}\right]}$$

For case (ii), above solutions are valid with b = 0.

Oscillatory case

$$i = \frac{2\, Q_o\, e^{-at}}{\sqrt{(4LC - R^2C^2)}}\ \mathrm{Sin}\ \beta t$$

$$\text{and } q = \frac{2\, Q_o \sqrt{LC}}{\sqrt{(4LC - R^2C^2)}}\ e^{-at}\ \mathrm{Sin}\ (\beta t + \theta)$$

where

$$\beta = \sqrt{\left[\frac{1}{LC} - \frac{R^2}{4L^2}\right]}$$

$$\text{and } \theta = \tan^{-1} \frac{\sqrt{(4LC - R^2C^2)}}{RC}$$

Design considerations :

The fast bank is charged to a higher voltage compared to the slow bank. On closing the ignitron switch, the fast bank discharges with its time constant till its voltage falls to that of the slow bank which then starts discharging and maintains current for a longer duration.

The acceptable drop in capacitor voltage ΔV over a time Δt and the value of bank capacitance C are related as

$$C = \frac{I\ \Delta t}{\left(\frac{\Delta V}{V}\right) \times V}$$

For 10% drop

$$C = \frac{I\ \Delta t}{0.1V}$$

Present status :

TF, VF and JH bank rating

Name	Voltage	Capacitance in millifarad
TF	1200v	500
VF	250V	800
JH	750V	400

JH and VF banks are ready while TF bank development is going on.

Capacitors used :

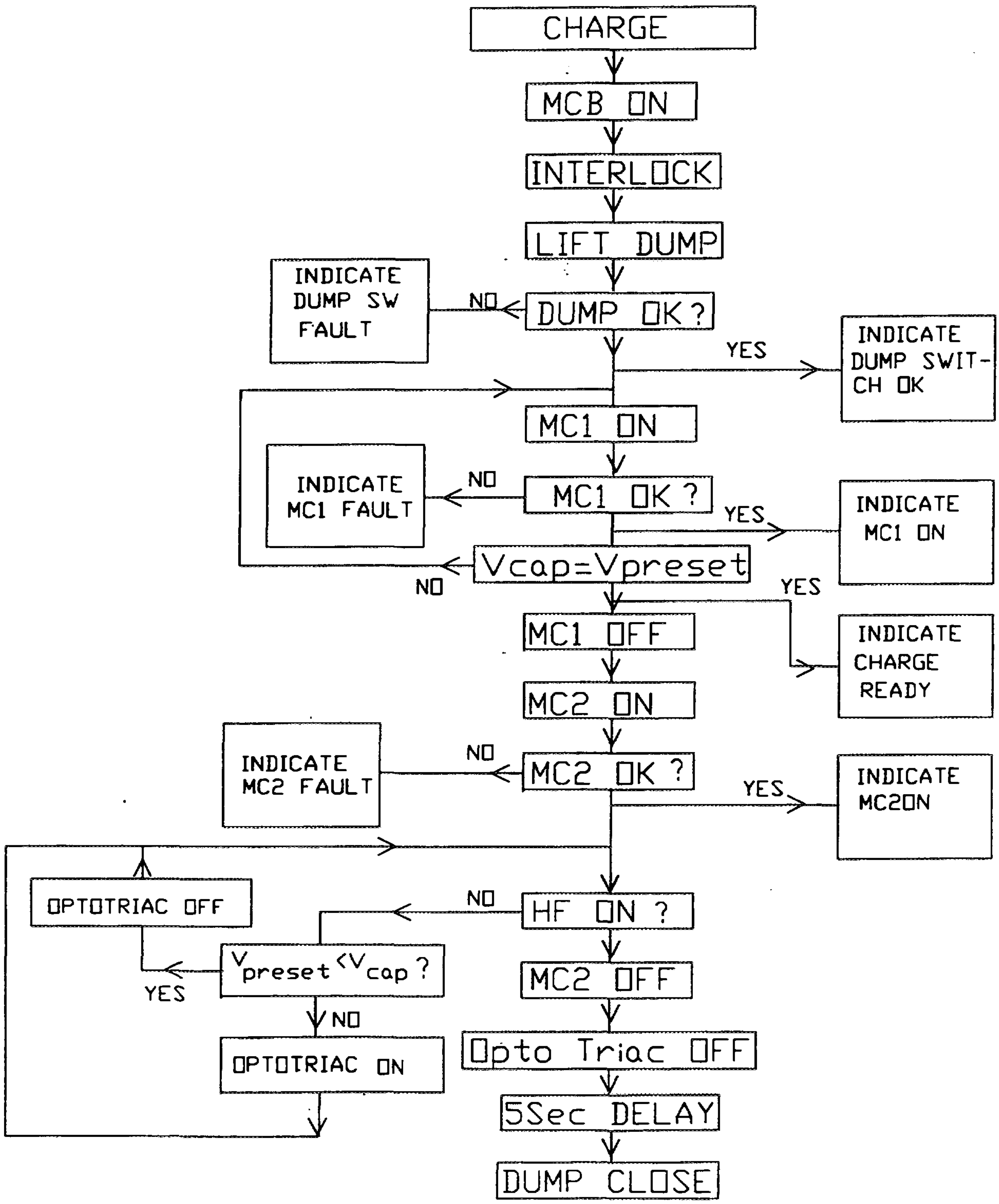
Make	:	Rescon (India)
Value	:	10 millifarad/250V
Leakage current	:	2 mA

Power supplies : Full wave bridge

Transformer	Phase	Voltage	KVA
TF	3	P 220 S 600V/1200V each phase	25
VF	1	220 250V	1.5
JH	1	220 750V	7.5

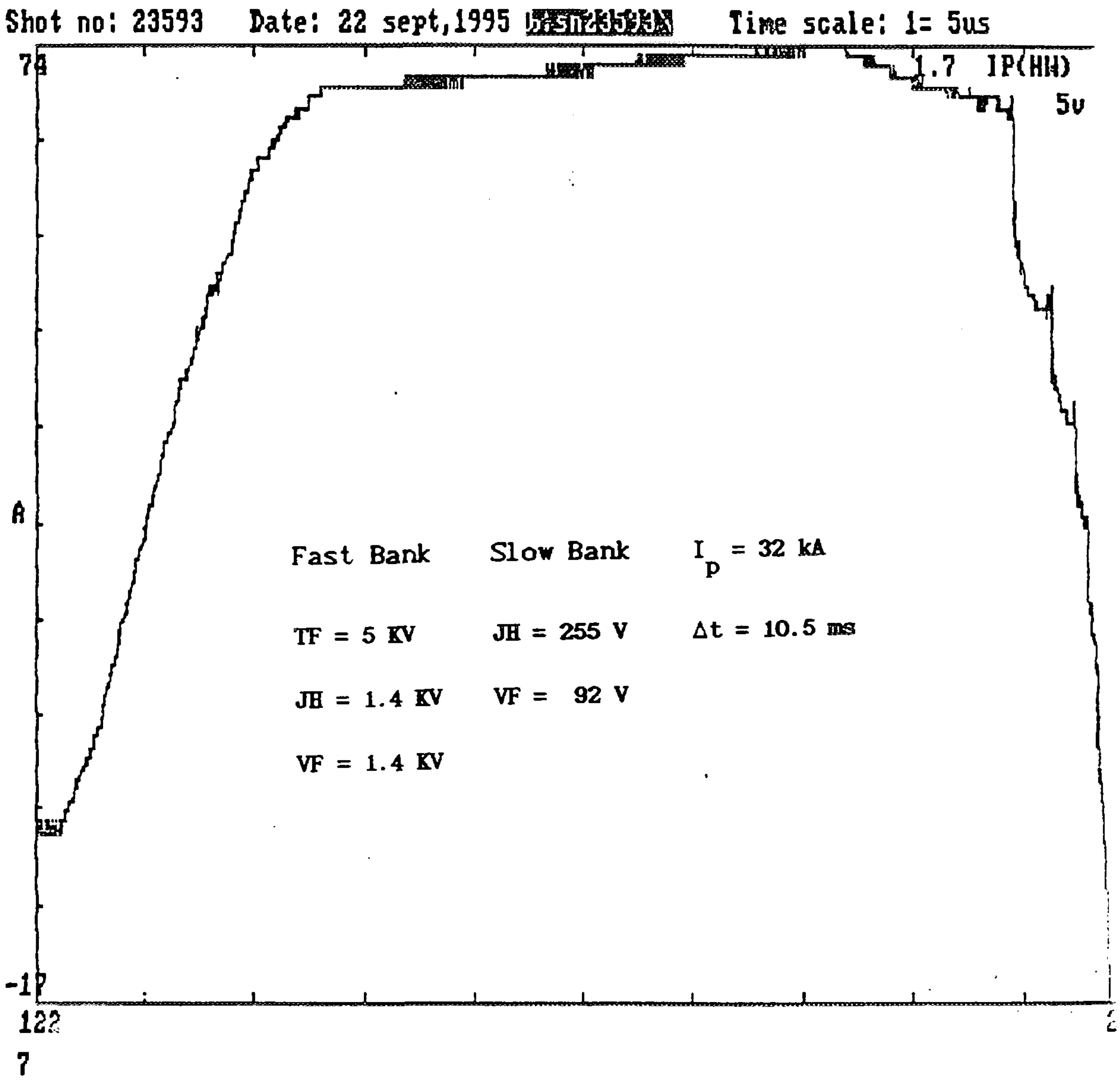
Control circuit :

It ensures that the dump switch is liftted before the SB can be charged or discharged. A few other interlocks are okayed before the operation of charging can be initiated. The scheme is shown as follows.



CHARGE
MCB ON
INTERLOCK
LIFT DUMP
DUMP OK?
NO
INDICATE DUMP SW FAULT
YES
INDICATE DUMP SWIT-CH OK
MC1 ON
MC1 OK ?
NO
INDICATE MC1 FAULT
YES
INDICATE MC1 ON
Vcap=Vpreset
NO
YES
INDICATE CHARGE READY
MC1 OFF
MC2 ON
MC2 OK ?
NO
INDICATE MC2 FAULT
YES
INDICATE MC2ON
HF ON ?
NO
OPTOTRIAC OFF
Vpreset<Vcap ?
YES
NO
OPTOTRIAC ON
MC2 OFF
Opto Triac OFF
5Sec DELAY
DUMP CLOSE

Result :



Shot no: 23593
Date: 22 sept,1995
Time scale: 1= 5us
74
1.7 IP(HH)
5v
A
-17
122
7
Fast Bank
Slow Bank
I_p = 32 kA
TF = 5 KV
JH = 255 V
Δt = 10.5 ms
JH = 1.4 KV
VF = 92 V
VF = 1.4 KV