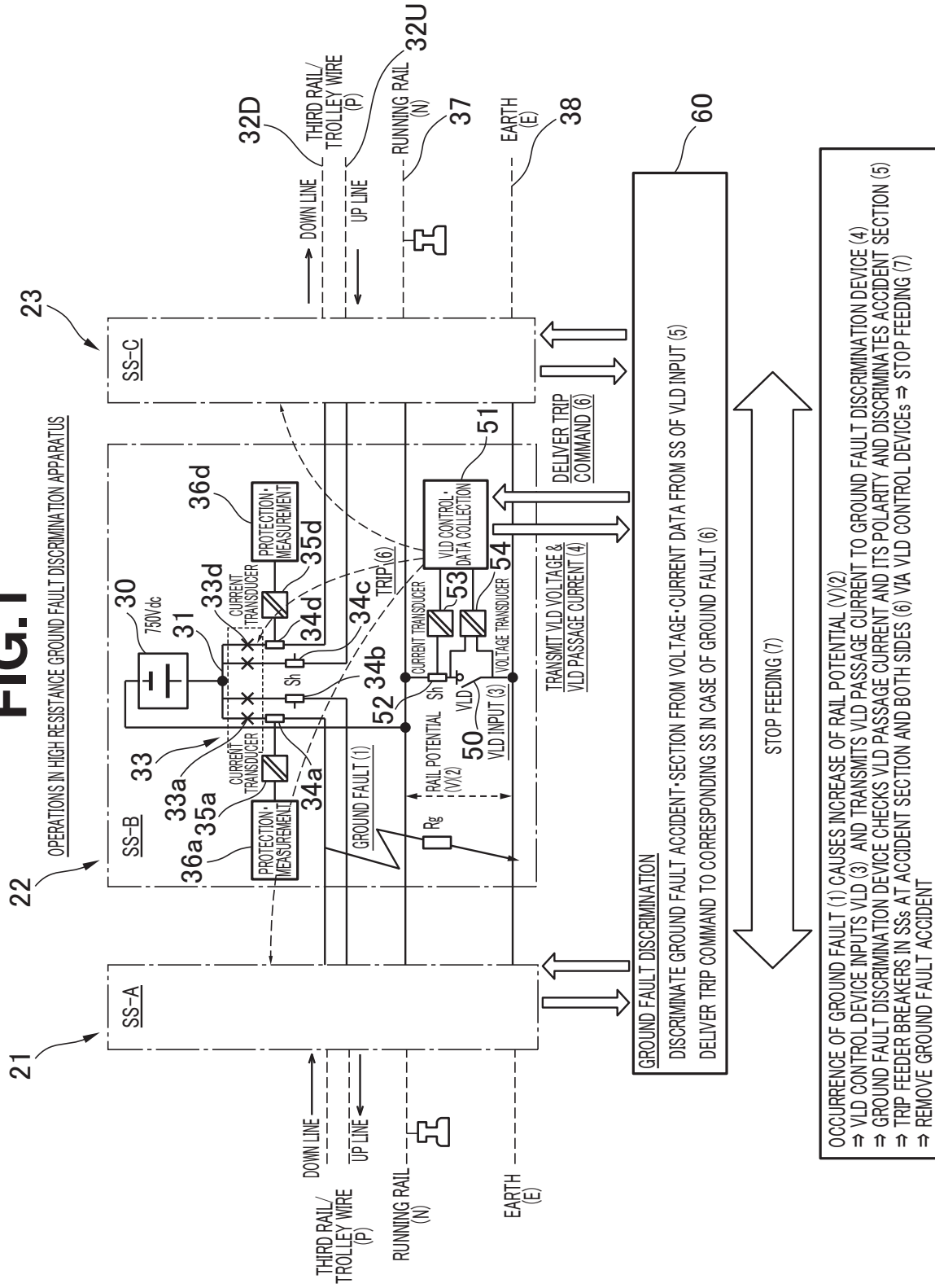
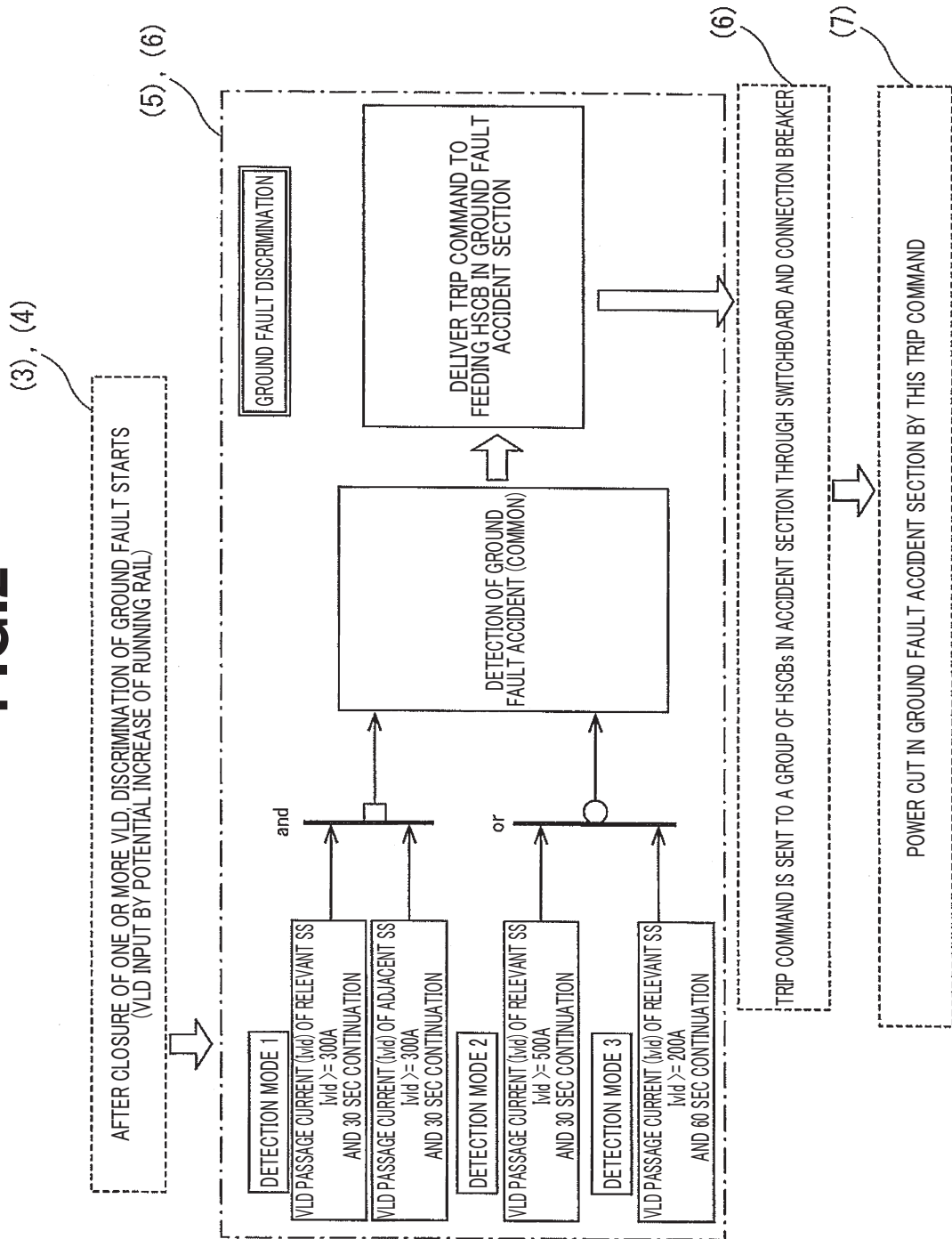


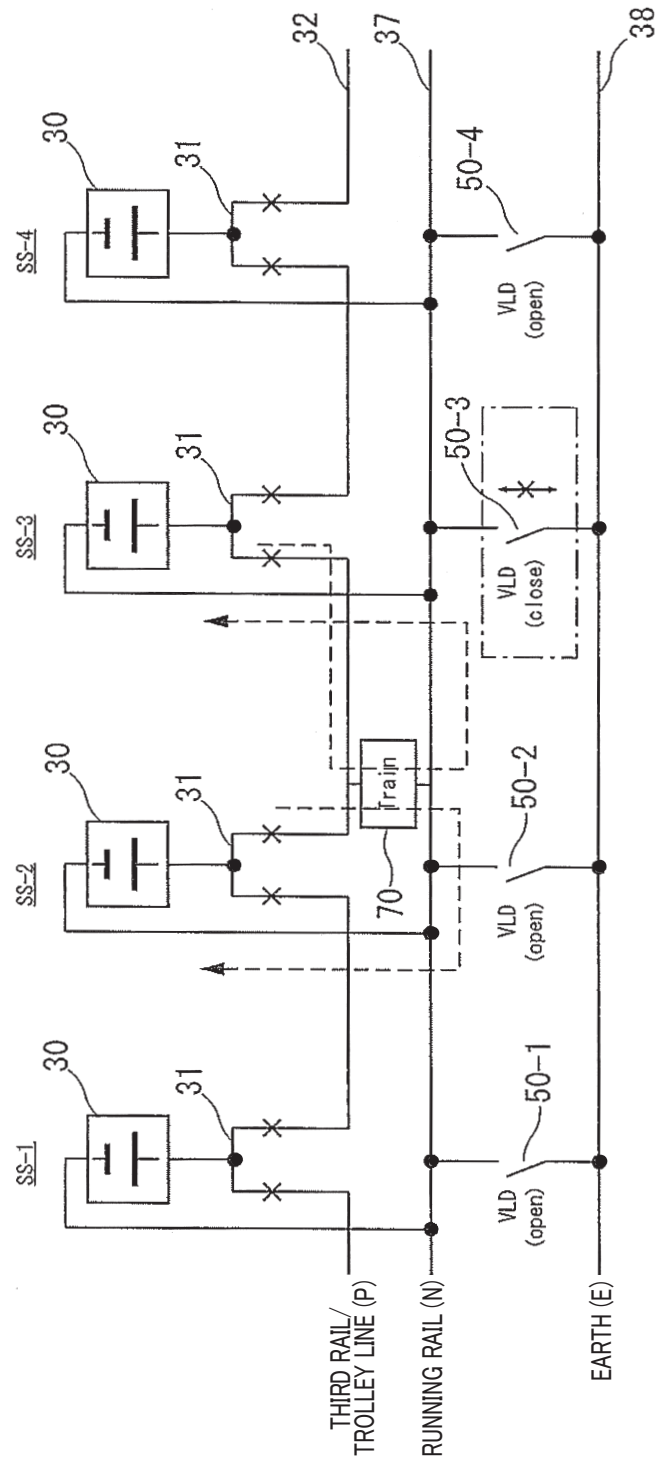
FIG.1

NEW DC GROUND FAULT DETECTION TECHNIQUE (GROUND FAULT DETECTION APPARATUS)

FIG.2

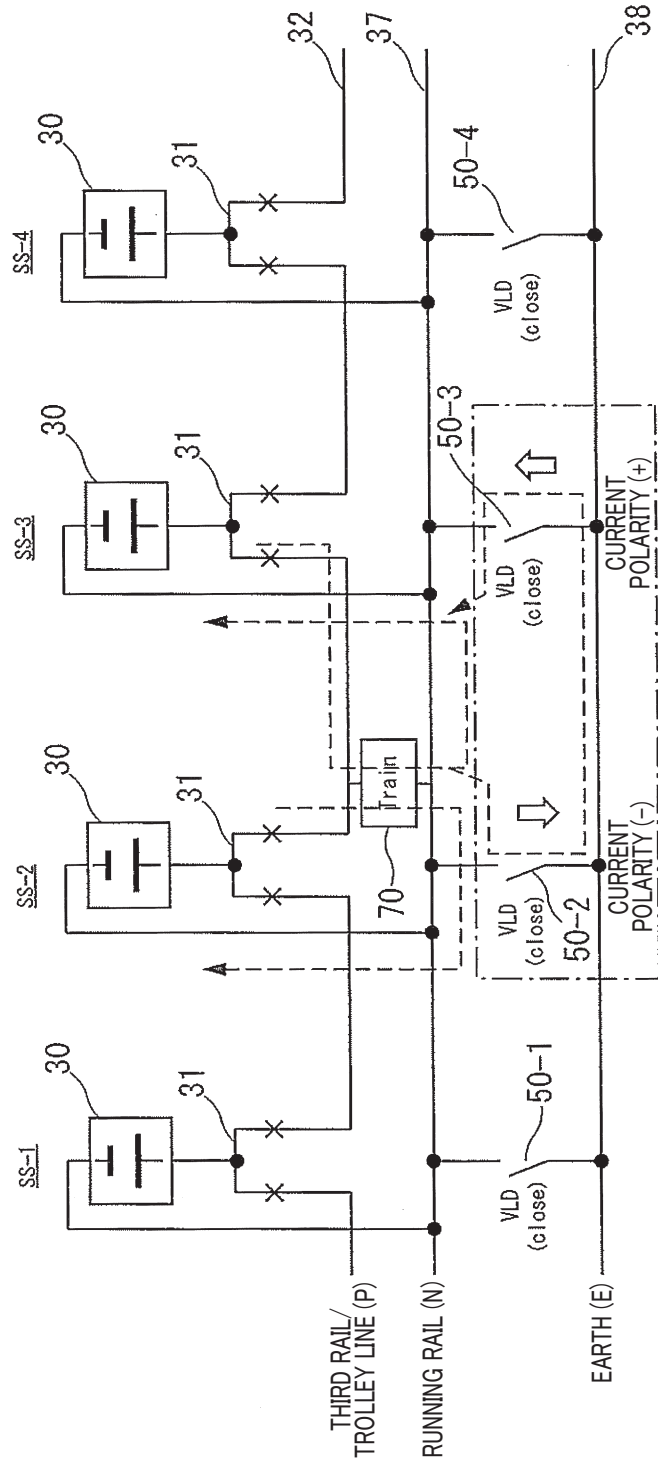
EXAMPLE OF DC GROUND FAULT DETECTION WITH GROUND FAULT DISCRIMINATION APPARATUS

FIG. 4

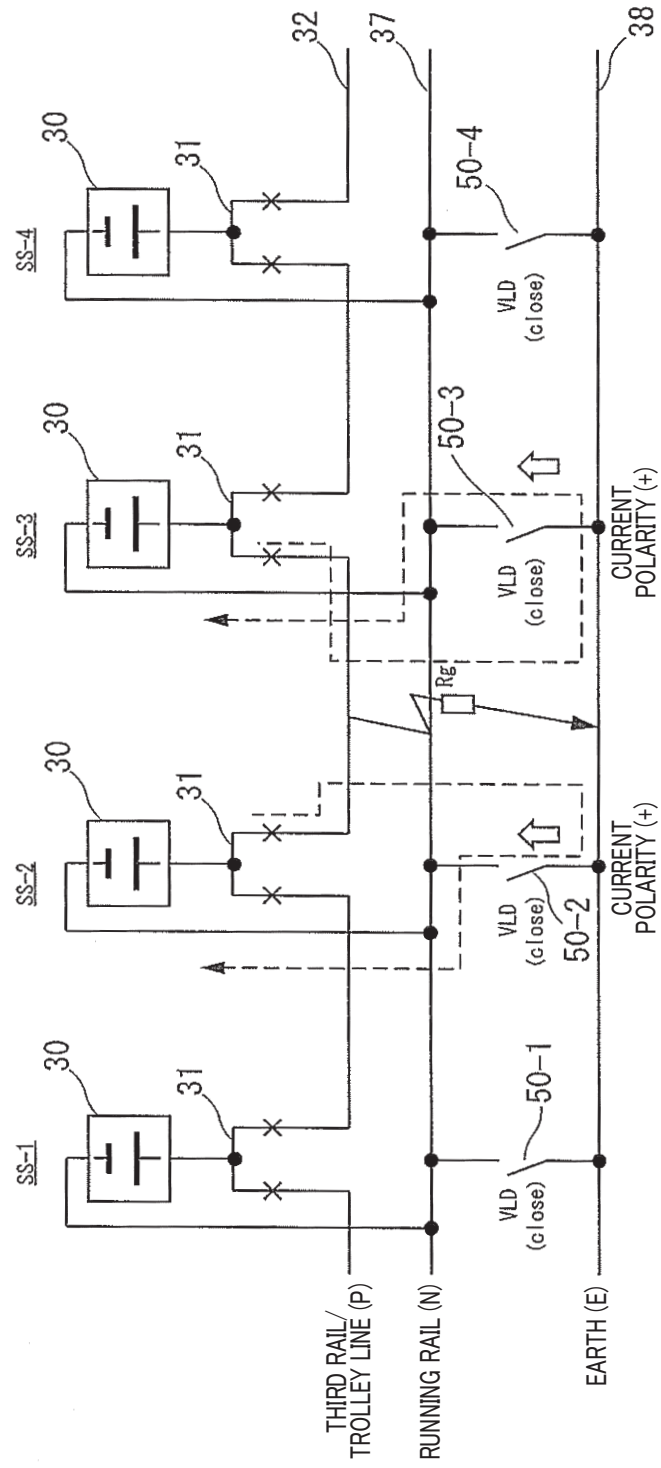


LOAD OF ELECTRIC CAR IS PRESENT AND ONLY ONE VLD IS CLOSED
(VLD PASSAGE CURRENT (I_{vld}) ≈ 0A BECAUSE OF OPEN LOOP TO LOAD CURRENT)

FIG.5



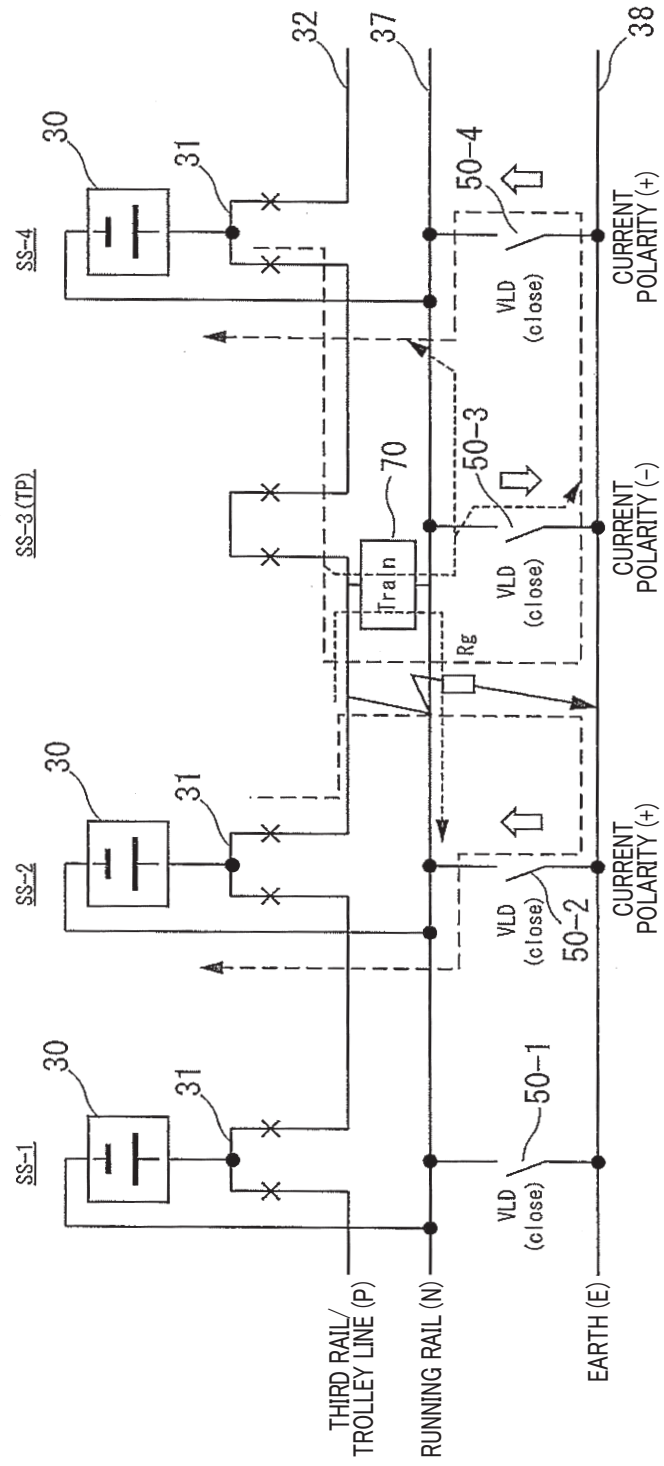
LOAD OF ELECTRIC CAR IS PRESENT AND TWO OR MORE VLDs ARE CLOSED
(VLD PASSAGE CURRENT (I_{vd}) IS GENERATED BECAUSE OF OPEN LOOP TO LOAD CURRENT)

FIG.6

FLOW OF ACCIDENT CURRENT IN NOLOAD STATE
(FLOW THROUGH VLD FROM GROUND TO RAIL (POLARITY +))



FIG.8



FLOW OF ACCIDENT CURRENT IN LOAD STATE OF ELECTRIC CAR (TIE POST TP INCLUDED)

FIG.9

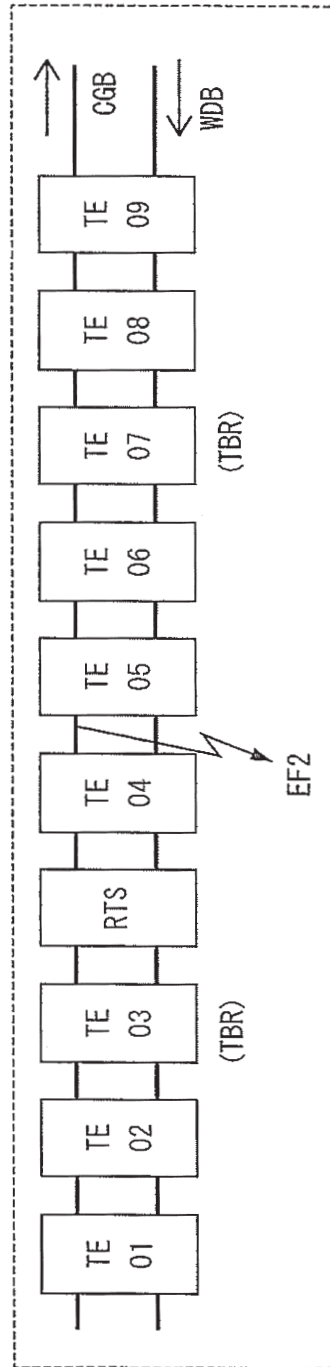
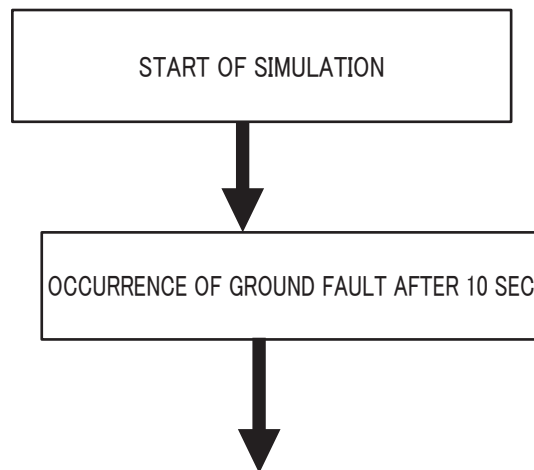


FIG.10

POTENTIAL INCREASE BETWEEN RAIL-GROUND (VLD VOLTAGE $\geq 300\text{V}$)

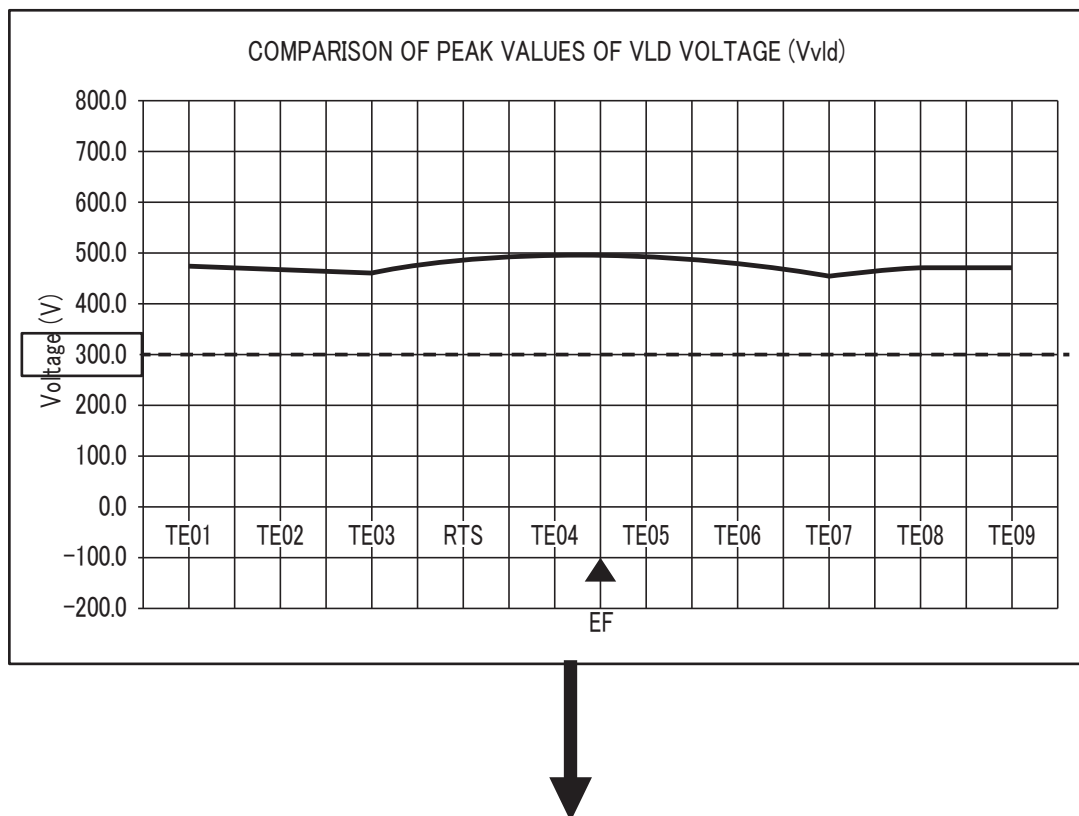


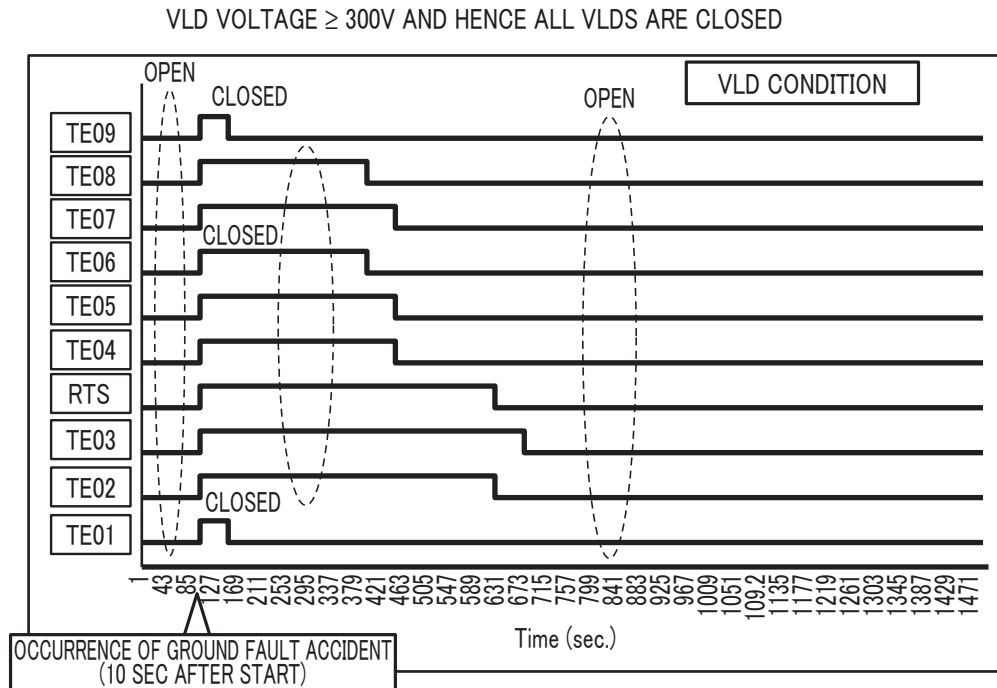
FIG.11

FIG.13

VLD CURRENT MEETS GROUND FAULT DETECTION THRESHOLD?

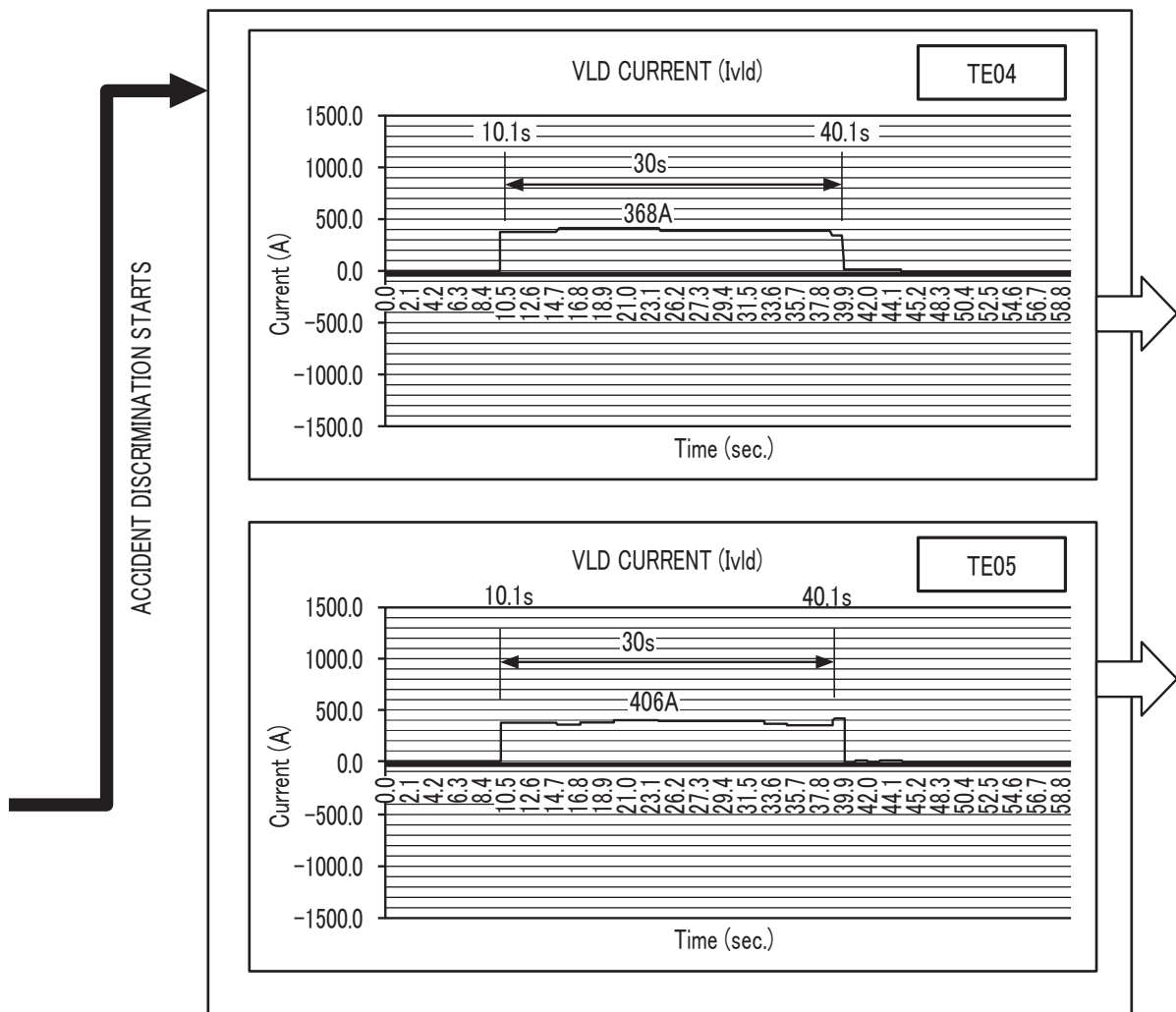


FIG.14

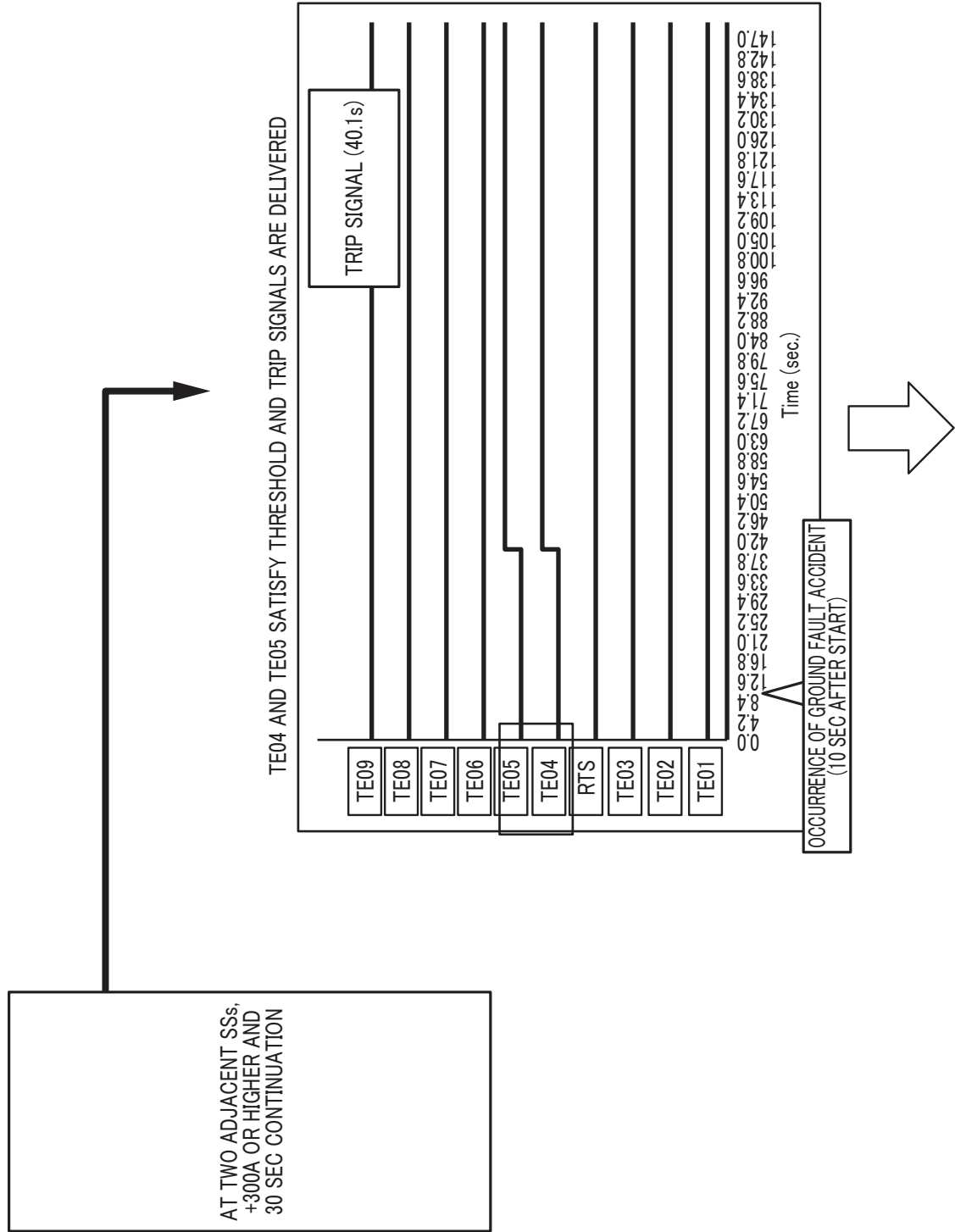


FIG.15

CONNECTION SHUTOFF SIGNALS FROM TE04 AND TE05 TO ADJACENT SUBSTATIONS (LOCAL SWITCHBOARD FUNCTION)

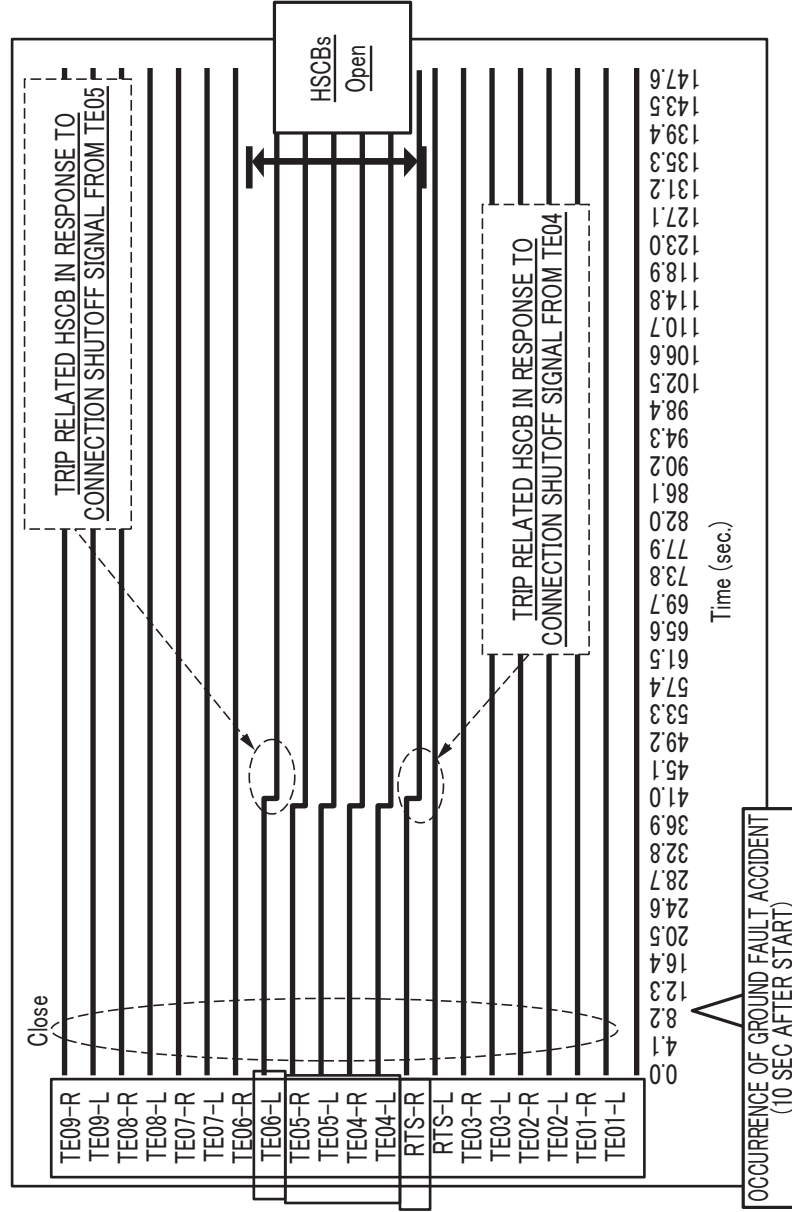


FIG.17

CALCULATION EXAMPLE OF MOVING AVERAGE OVER 5 MIN PERIOD IN EACH SUBSTATION

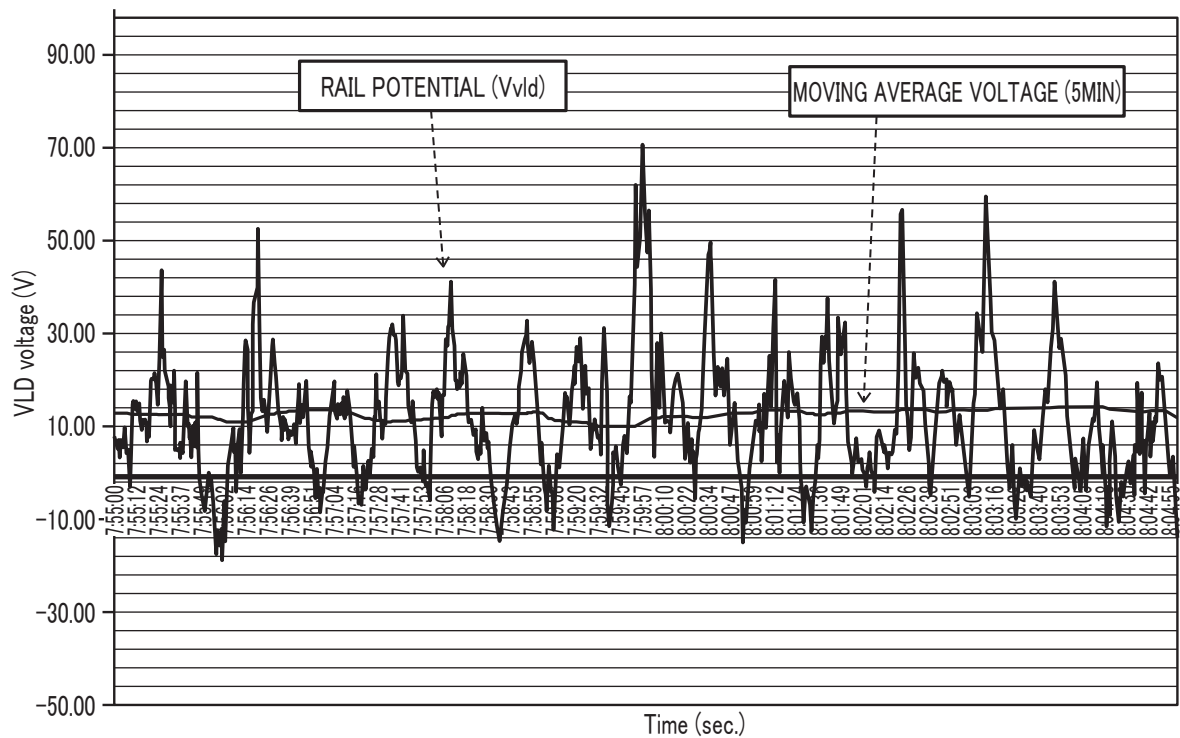
$$\text{MOVING AVERAGE VOLTAGE (V}_n\text{) AT INSTANT } n = \frac{V_1 + V_2 + V_3 + \dots + V_{n-1} + V_n}{N \text{ (5 MIN)}}$$

$$\text{MOVING AVERAGE VOLTAGE (V}_{n+1}\text{) AT INSTANT } n+1 = \frac{V_2 + V_3 + V_4 + \dots + V_n + V_{n+1}}{N \text{ (5 MIN)}}$$

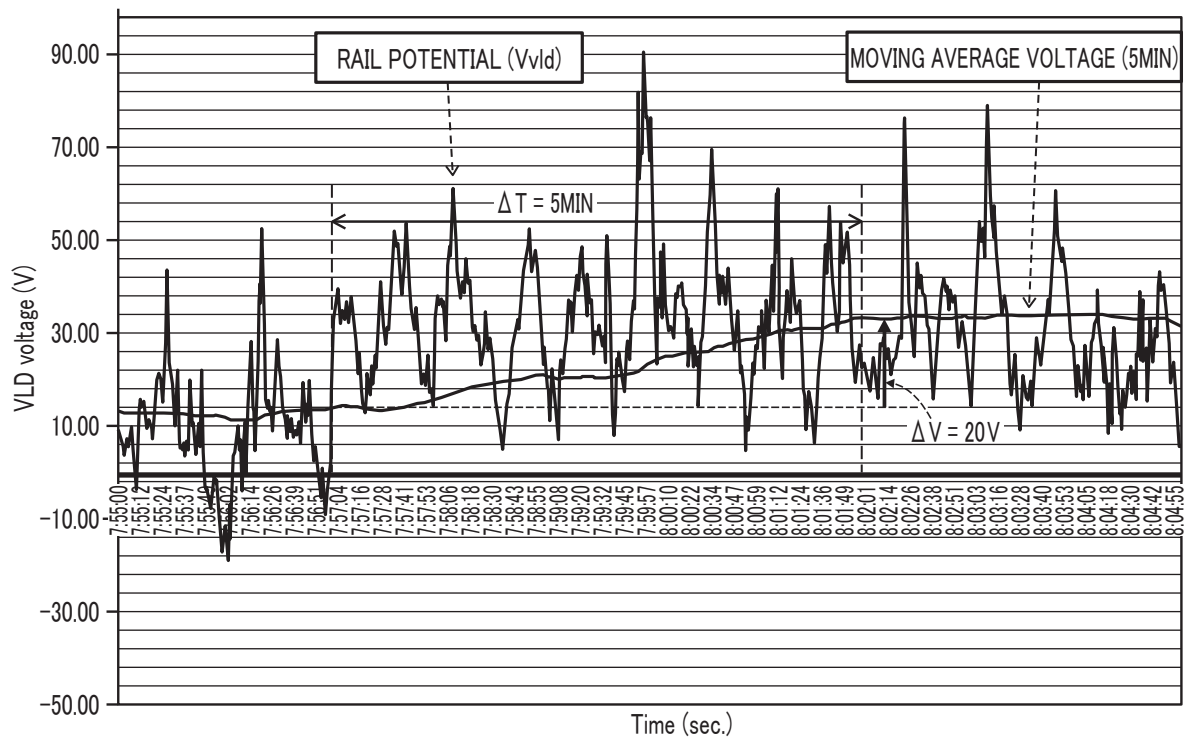
$$\text{MOVING AVERAGE VOLTAGE (V}_{n+2}\text{) AT INSTANT } n+2 = \frac{V_3 + V_4 + V_5 + \dots + V_{n+1} + V_{n+2}}{N \text{ (5 MIN)}}$$

.....

CALCULATION EXAMPLE OF MOVING AVERAGE VOLTAGE (5 MIN)

FIG.18

RAIL VOLTAGE AND MOVING AVERAGE VOLTAGE IN STEADY STATE

FIG.19

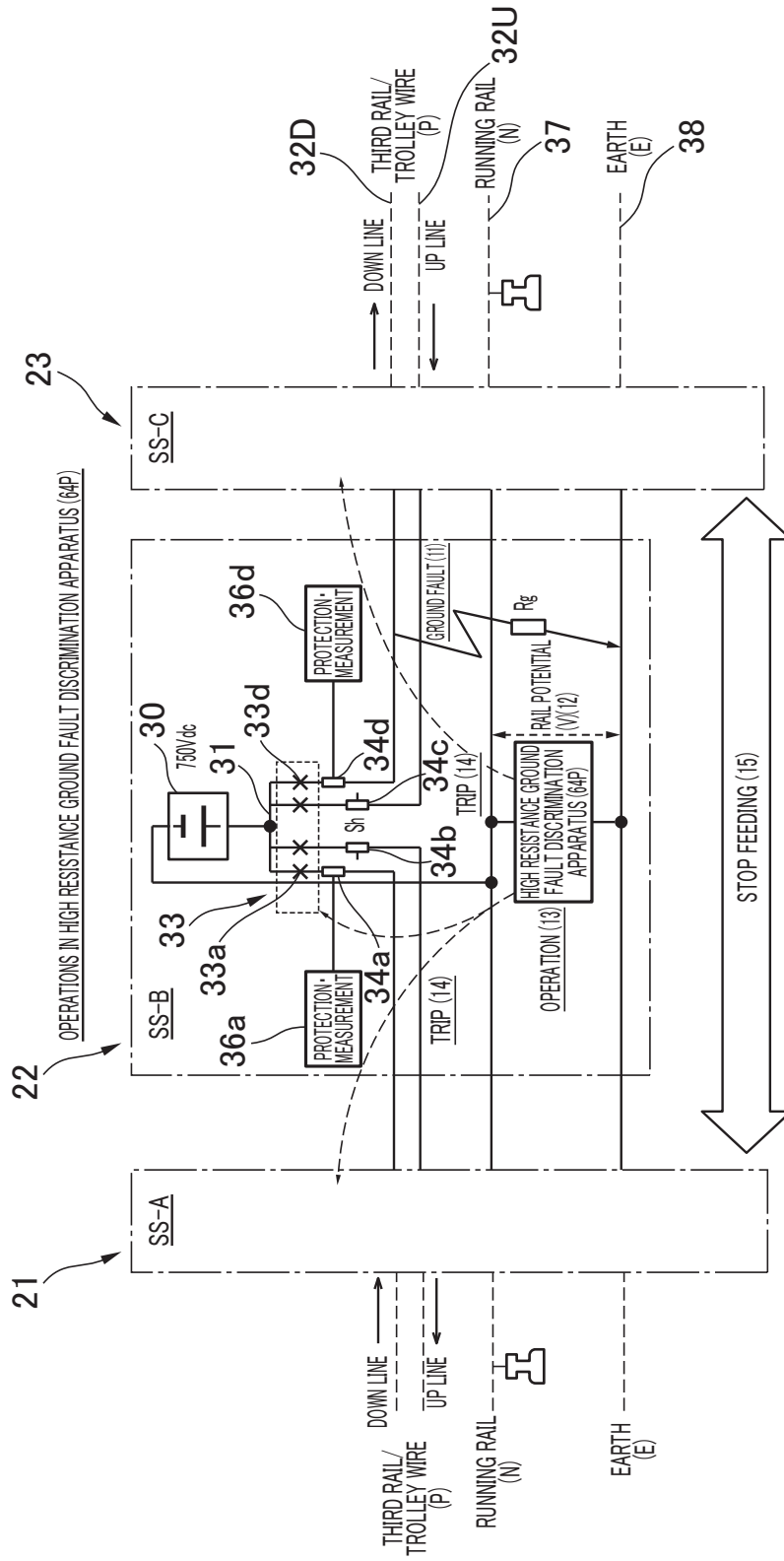
RAIL VOLTAGE WAVEFORM AND MOVING AVERAGE VOLTAGE AT TIME OF HIGH RESISTANCE GROUND FAULT

FIG.20

	TPSS	TIME SCHEDULE	MAX (V)	MIN (V)	MOVING AVERAGE MAX (V) 5MIN
1	A	2015/9/5 17:02 ↓ 2015/9/6 16:58	56.60	-61.32	5.970
2	B	2015/9/7 18:33 ↓ 2015/9/8 18:27	33.20	-20.16	4.923
3	C	2015/9/7 17:48 ↓ 2015/9/8 17:33	113.04	-72.40	12.537
4	D	2015/9/6 17:20 ↓ 2015/9/7 17:04	84.28	-64.76	9.836
5	E	2015/9/5 16:51 ↓ 2015/9/6 16:35	66.28	-56.52	5.884
6	F	2015/9/5 17:15 ↓ 2015/9/6 16:59	64.16	-59.40	9.210
7	G	2015/9/5 17:01 ↓ 2015/9/6 16:48	95.00	-64.44	13.327
8	H	2015/9/5 16:50 ↓ 2015/9/6 16:43	81.56	-56.56	6.588
9	I	2015/9/5 18:28 ↓ 2015/9/6 18:13	84.44	-66.76	5.483
10	J	2015/9/6 16:46 ↓ 2015/9/7 16:58	94.72	-63.28	13.622
11	K	2015/9/5 18:18 ↓ 2015/9/6 18:01	88.84	-57.24	6.696
12	L	2015/9/5 18:19 ↓ 2015/9/6 18:08	68.44	-58.04	8.814
13	M	2015/9/5 18:17 ↓ 2015/9/6 17:59	42.76	-48.40	6.319
14	N	2015/9/5 18:00 ↓ 2015/9/6 17:57	98.08	-69.16	12.059
15	O	2015/9/9 17:48 ↓ 2015/9/10 17:45	98.96	-65.52	18.246

MAXIMUM AND MINIMUM VALUES OF RAIL VOLTAGES AND MAXIMUM VALUES OF MOVING AVERAGE (5 MIN) IN 15 SUBSTATIONS

FIG. 21



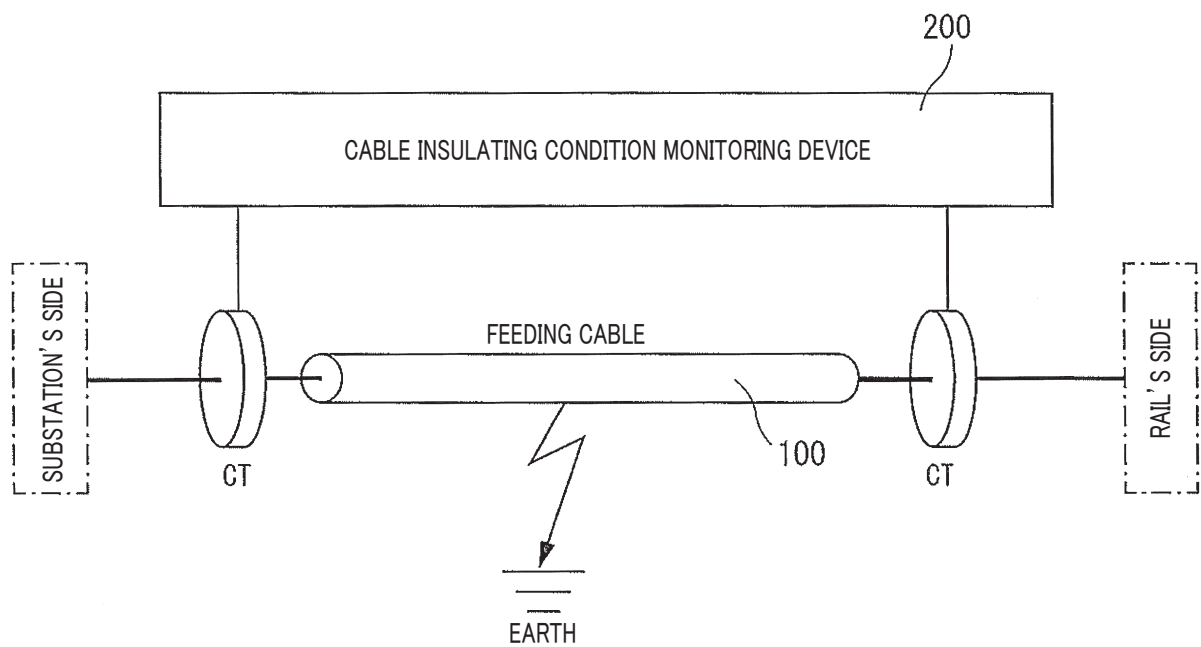
OCCURRENCE OF GROUND FAULT (11) CAUSES INCREASE OF RAIL POTENTIAL (V)(12) ⇒ OPERATION OF 64P (13) ⇒ TRIP FEEDER BREAKERS IN SSSs AT ACCIDENT SECTION AND BOTH SIDES (14) ⇒ STOP FEEDING (15) ⇒ REMOVE GROUND FAULT ACCIDENT

PROBLEM OF 64P TYPE

SINCE INCREASE OF RAIL POTENTIAL (V) BY GROUND FAULT ACCIDENT SPREADS WIDE, 64P OUTSIDE ACCIDENT SECTION MAY BE OPERATED AND FEEDING STOPPAGE MAY SPREAD WIDE

CONVENTIONAL DC GROUND FAULT DETECTION TECHNIQUE (GROUND FAULT TO OVERVOLTAGE PROTECTION RELAY 64P)

FIG.22



CONVENTIONAL METHOD OF DETECTING INSULATION DEGRADATION OF DC CABLE