GER-3225

General Electric Model Power System

GENERAL ELECTRIC MODEL POWER SYSTEM

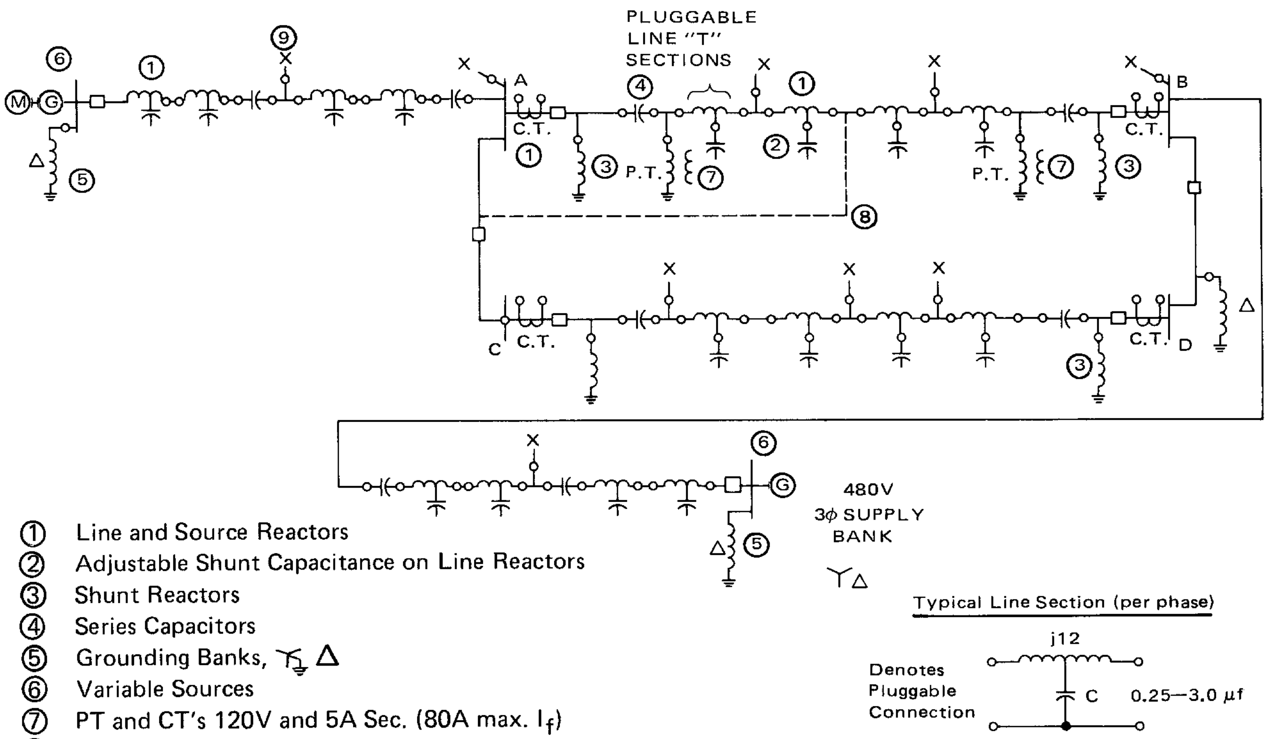
The General Electric Model Power System (MPS) is a transmission-line simulator utilized to determine the response of static terminal equipments to various line-fault conditions. In operation, the MPS can simulate lines up to approximately 400 miles in length and faults can be applied in several locations. The equipments under test are connected to the MPS and their performance is recorded on either a four trace oscilloscope (Tektronix 5103) or a 30 trace oscillograph (Midwestern 1200).

The MPS is a three-phase simulator operating at 480 volts 60 Hz. A simple diagram of the system is shown in Fig. 1. All components of the simulator are brought out to a plug board, and may be connected in any desired arrangement.

There are 16 sets of 12-ohm high angle (88 degrees) reactors which may be connected to make up source and line impedances. Each set consists of three reactors, one per phase. The eight sets normally used for line sections have shunt capacitors that are adjustable in steps, and provision for separating the line-to-line and line-to-ground capacitance effects. Range of adjustment is 0.25 mfd to 3.0 mfd total capacitance. The eight sections normally used for source sections have 3.0 mfd total capacitance per phase, non-adjustable, with 2.0 mfd connected to the neutral of the system, and 1.0 mfd connected in wye to the other phases.

There are six sets of shunt reactors and each reactor is adjustable in six steps between 400 ohms and 800 ohms. These may be connected anywhere on the system.

There are eight three-phase series capacitor banks. Six of these are equipped with capacitor gap-flash simulators and are intended for use at the ends of the two parallel lines and at the connection of the sources to the buses. The other two are intended for use only where a large source impedance is used and fault current through the capacitors is not large enough to exceed their voltage rating (330 V). The line capacitors are adjustable from 11.8 to 109 ohms, the two at the bus end of the source are adjustable from 10.6 to 55 ohms, and the two without gap-flash simulators are adjustable from 5.9 to 55 ohms. In some cases, these



① Line and Source Reactors
② Adjustable Shunt Capacitance on Line Reactors
③ Shunt Reactors
④ Series Capacitors
⑤ Grounding Banks, Y, Δ
⑥ Variable Sources
⑦ PT and CT's 120V and 5A Sec. (80A max. I_f)
⑧ For 3 Terminal Line Representation
⑨ 9 Pluggable Fault Locations

Fig. 1. Schematic representation of Model Power System

ranges can be exceeded, if all of the banks are not in use at the same time, by interconnecting capacitors from the unused banks to those in use. Gap-flash setting is continuously adjustable between 80 volts and 300 volts, rms.

Zero sequence impedance is coupled into each line section through a "four winding reactor" which has one winding in series with each of the phases of the line reactor, and the fourth winding is connected to the necessary reactance value to produce the desired zero sequence impedance. For any balanced three-phase condition, or for a phase-to-phase fault not involving ground, there is no net voltage across the fourth winding and the zero sequence impedance is not in the circuit. For any fault involving ground or any other dissymmetry where zero sequence current would flow, there is a voltage across the fourth winding and the reactance in series with the winding is reflected into the phase conductors. A typical arrangement would be an 8 ohm reactor connected to the fourth winding representing 1/3 of the added zero sequence impedance. The net effective zero sequence is 12 ohms of the main reactor, plus 3 times 8, or 36 ohms total, which is 3 times the positive sequence impedance, a typical value. Reactors of 4 ohms and 12 ohms are also available and may be used for this purpose. Also, 3 ohm resistors can be added in series with the 8 ohm reactor to produce a 75 degree angle for the zero sequence impedance.

These four-winding reactors may also be used, along with 1:1 current transformers, to couple together corresponding sections of two parallel lines and to simulate the mutual impedance between them. To do this, the fourth-winding reactor mentioned, is replaced by two reactors, one coupled to the opposite line section and one isolated from that section. This gives separate control of Z_0 and Z_M. There are 10 four-winding reactors, 5 mutual CTs, 15 tapped reactors to provide either 4, 8 or 12 ohms and 10 three-ohm resistors.

There are three wye-delta grounding banks available. One is connected permanently to the right-hand end of the MPS, and the other two are pluggable. These may be connected to the bus, for example, to represent a condition where the zero sequence impedance is less than the positive sequence. Reactors can be inserted between the neutrals of any of the grounding banks and the neutral bus of the MPS to vary the zero sequence impedance of the sources.

Load flow over the system can be controlled by a phase-shifting bank at the left end of the MPS, which can be connected to produce either a 30 degree or a 60 degree phase shift between the two ends of the system. In addition, a generator driven by a dc motor can be connected to one end of the system and the speed of the motor can be changed slightly to pull the generator out of step with the system. This can also be used to produce load flow at system angles other than 30 or 60 degrees but it is not as stable with time as is the phase-shift method.

Current transformers normally used are 1:1 ratio. Provisions are available for using 1.5:1, 2:1, 1:1.5 or 1:2 ratios by using auxiliary CTs or by using two sets of CTs. Main CTs are approximately 10L200 accuracy class. Additional windings are available to produce the equivalent of 10L20 accuracy class.

Voltage transformers with a 4:1 ratio are available to step down the 480 volts of the MPS to the 120-volt rating of protective relay circuits. Because they may draw rather large and unrealistic magnetizing currents under some transient conditions, there is available a high input impedance electronic amplifier voltage source which produces voltage waves identical to those from the magnetic transformers, and this is normally used as the ac voltage source. In addition, this voltage source can be modified to simulate the output of a GE CD-31 capacitor transformer (CVT). When this CVT simulation is used, it is necessary to model the burden on the CVT also, since the transient response is affected by the burden.

There is a fault type selector switch on the front of the control panel with 10 fault types (AG, BG, etc.), which permits a rapid change from one fault type to another at any fault location. Fault initiation is by a static switch with 0-360 degree control of incidence angle. Each pole of the static switch can be delayed independently by as much as two cycles to simulate an evolving fault (AG to ABG, for example). Duration of the fault can be varied from 1.5 cycles to 12 cycles by a variable control on the switch. The static switch can also be used to check line-pickup and line-closing performance by plugging it in place of one of the line contactors. Controls are available for simulating pre-insertion resistors on power circuit breakers and for simulating differences in all three breaker pole closing times up to two cycles maximum. The triggering of the oscilloscope and the starting of the oscillograph are coordinated with the fault initiation switch to display the transient conditions of primary interest.

Line breakers shown on Fig. 1 are ac contactors. A trip and reclose control scheme is available so that the breakers on either line can be tripped either together or sequentially and then reclosed after an independently adjustable delay. The tripping of these contactors may be initiated by the relays under test, for internal faults, or by a delayed signal from the static fault switch for external faults.

There are three sets of reactors without shunt capacitance, in addition to those used for zero sequence impedance. One set consists of 12 reactors that are 3 ohms total tapped at 1 and 2 ohms. One set consists of 12 reactors that are 0.6 ohms total tapped at 0.2 and 0.4 ohms. The third set consists of 12 standard GE test reactors (6054975G1), each with taps at 0.5, 1, 2, 3, 6, 12 and 24 ohms.

Fault resistance for ground faults can be simulated by inserting a resistance that is continuously adjustable from several hundred ohms down to 20 ohms.

There are available two impedances to represent arc drop. Each consists of two strings of six silicon diodes, with the strings connected in parallel with opposite polarity.

The three-phase simulator is shown in Fig. 2.

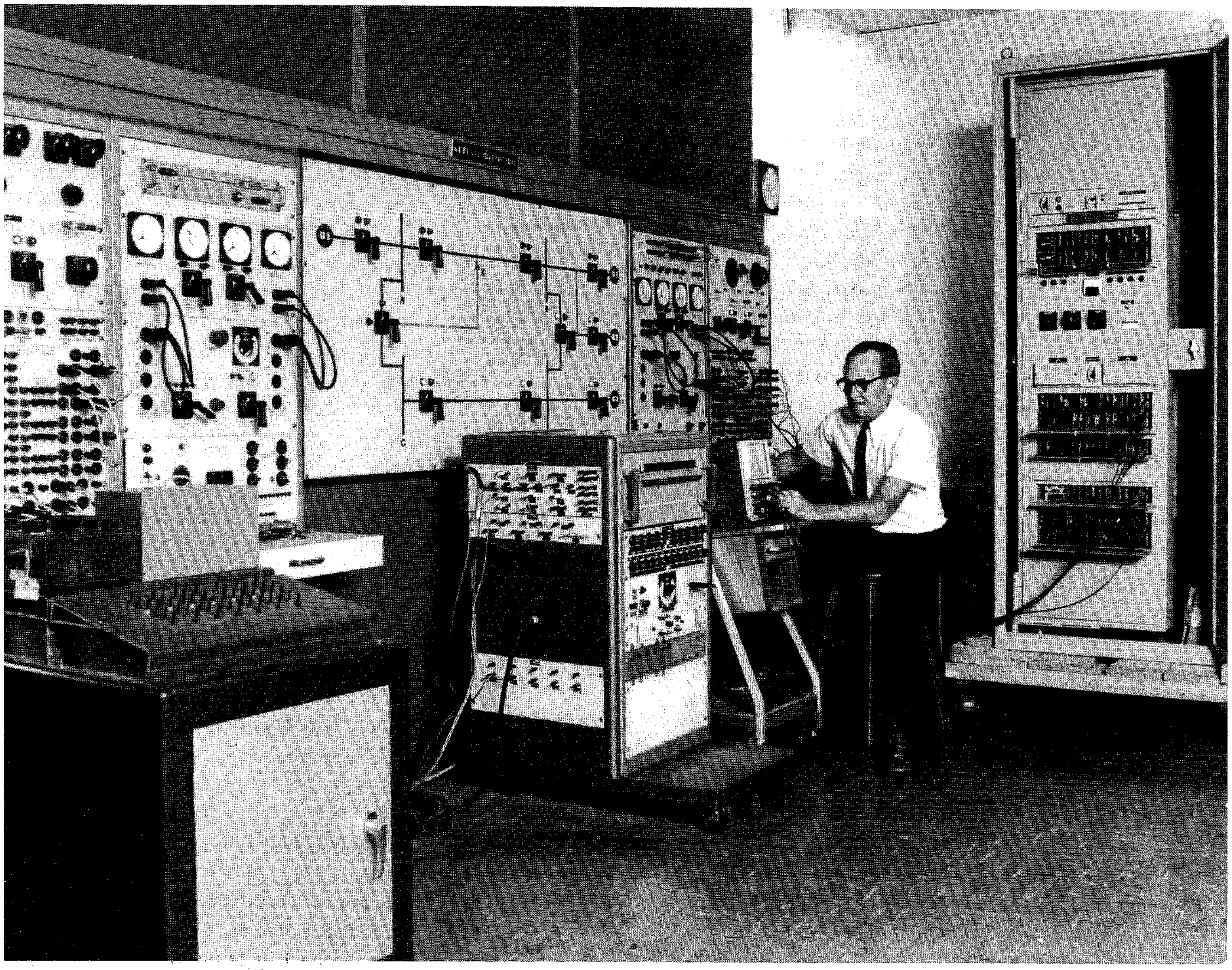


Fig. 2. GE Model Power System

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GENERAL ELECTRIC

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PRINTED IN U.S.A.