Electrical Systems - Course 135

COMPOSITE ELECTRICAL PROTECTIVE SCHEMES: PART II

TURBINE-GENERATOR: TRIPPING AND ALARM CIRCUITS

1.0 INTRODUCTION

Following on from Lessons 135.03-1 and 135.04-1, this lesson shows composite protective schemes for Turbine-Generators. The actions of the protection (fed from CT's and PT's) are described together with the tripping to the respective breakers and other devices. A simplified version of electrical protection diagram for a Turbine-Generator, and its associated circuits, is used to illustrate a typical protective scheme.

2.0 PROTECTION SYSTEMS FOR TURBINE-GENERATORS

Unlike large transformers, whose protections systems are to a large extent similar, the protection systems for turbine-generators vary a great deal. For example, the protection systems used on a 30 MW turbine-generator will be less complex than the protection for a 500 MW or an 800 MW turbine-generator.

Figure 1 shows a simplified single line protection diagram for a Turbo-Generator. Note that the main and unit services transformers are also shown.

2.1 Protection Details

The following protective features are used on Turbine-Generators. See Figure 1.

2.1.1 Generator Protection: Tripping

(G1) The main protection for the generator is provided by the differential relay, (87). Note that the zone of protection only covers the generator windings and connections close to the generator.

(G2) Ground fault protection is provided by relay (64). This relay will operate for a ground fault in the generator windings, main connections and in the two transformer windings **directly connected** to the generator.

(G3) Phase unbalance protection (46) protects the generator rotor against excessive heating due to phase unbalance. Lesson 135.02-1 explains the reasons for and the method of operation of this protection.

(G4) Loss of field protection (40) trips the generator if there is insufficient excitation for a given load. The relay has current input from the generator CT's and a potential input from the 13.8 kV PT's. When the generator has insufficient excitation for a given load, it may be operating at a **leading power** factor with a large load angle. The loss of field protection relay senses this condition and will trip the unit before the load angle becomes excessive and serious pole slipping occurs.

(G5) Generator inter-turn protection (60) relay operates from the output of the three potential transformers connected in open delta. Under healthy conditions, the output from the open delta is zero. Under inter-turn fault conditions, the phase voltages will not balance. Consequently, there will be a voltage output from the open delta and this output will operate the inter-turn protection relay.

(G6) Excitation rectifier overcurrent (51) relay is supplied from a current transformer which is connected between the exciter and the rectifiers. An excess of current taken by the rectifiers (or the dc system fed from the rectifiers) will operate the relay and trip the unit.

(G7) Underfrequency protection (81) is provided to protect the turbine-generator in the even of an excessive fall in **system frequency.** At 57.5 Hz, the trip is time delayed and at 56 Hz the trip is instantaneous. The protection is only in service after the HV breaker or breakers have been closed and only trips the HV breakers.

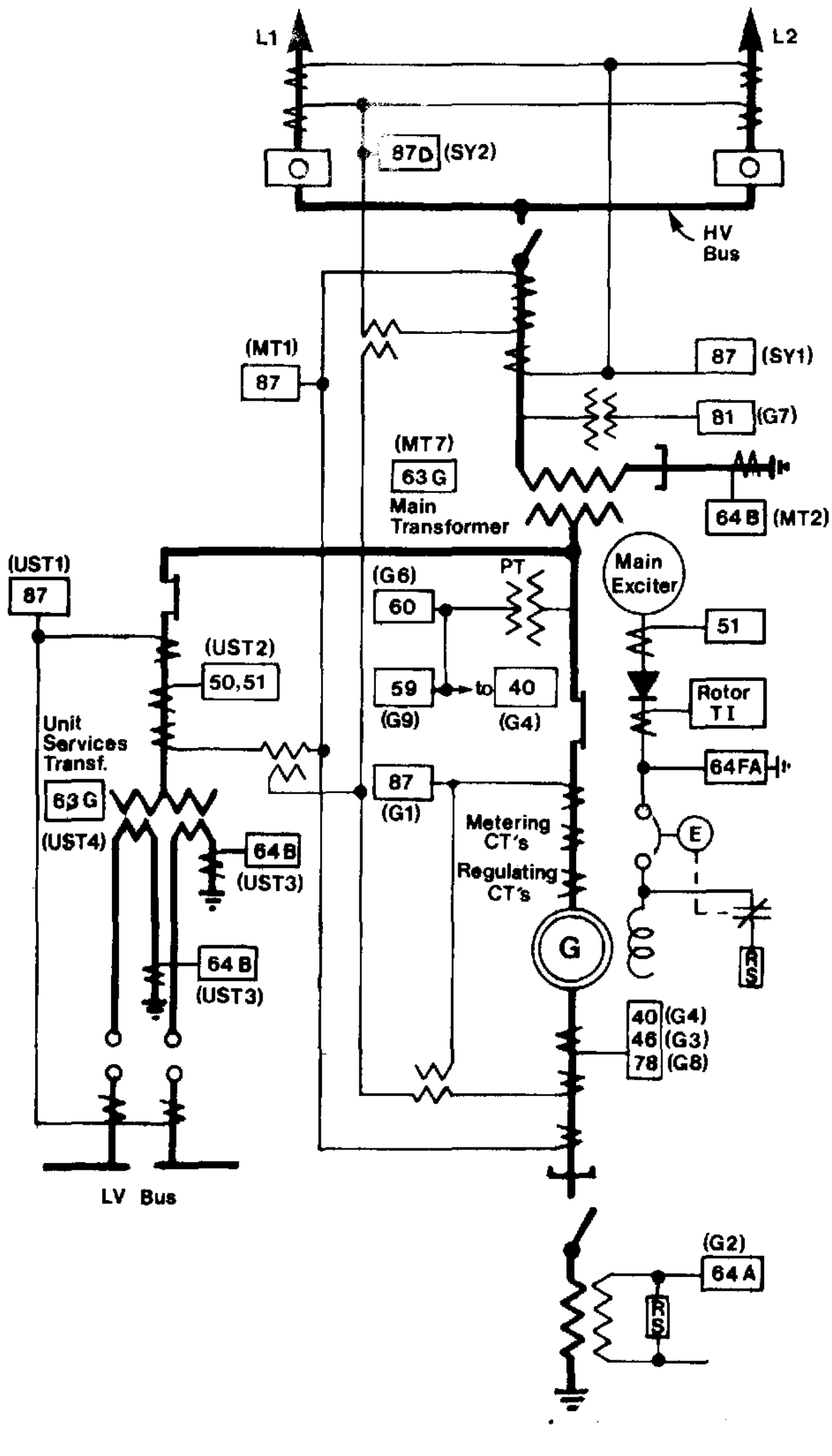

Figure 1: Simplified single line protection diagram for a turbine-generator.

(G8) Out of step protection (78). In the event of the generator coming out of synchronism with the 230 kV system, this protection will trip the 230 kV breakers. Instability in the generator on the system will ususally cause a generator to loose synchronism. The instability can be due to an excitation failure or a transmission fault which is slow to clear. Course 235 describes instability in detail.

(G9) Overexcitation protection (59) protects the generator during start-up. If the generator voltage to frequency ratio is too high it will cause **overfluxing** in the generator stator iron and in the iron cores of the main and services transformers. The problems associated with overfluxing are explained in Lesson 230.20-4. This protection will only trip the field breaker if the 230 kV breaker(s) are open. Once a 230 kV breaker is closed this protection is removed from service.

2.1.2 Generator Protection: Alarms

(i) Rotor ground fault relay (64 FA) will detect a ground fault on the generator rotor and its associated excitation system.

(ii) Rotor temperature indication (Rotor TI) gives a continuous indication of rotor temperature. If the rotor copper temperature exceeds the predetermined temperature setting, an alarm will be given in the control room.

(iii) Other alarms are provided to give warning of abnormal conditions in the following systems.

- hydrogen cooling
- hydrogen seals
- stator water

Details of these alarms are covered in the manufacturer's instruction book.

2.2 Unit Services Transformer

2.2.1 Tripping

(UST1) The main protection for the Unit Services transformer is provided by the differential relay (87). Note that the zone of this protection covers the transformer, LV cables and the LV breaker.

(UST2) Overcurrent protection is provided on the high voltage side of the transformer. The instantaneous relay, (50) is provided to ensure that when high values of fault currents occur, the fault is quickly cleared. The timed relay (51) has a lower current setting. It initiates tripping in the event of a persistant fault which is of low current magnitude.

(UST3) Ground fault protection is provided by relay (64). This relay will only operate for a ground fault in the unit services transformer LV windings, LV cables and LV bus. Note that this is **not** a differential protection. Consequently, the protected zone will depend upon the magnitude of the fault current and the relay setting.

(UST4) The gas detector relay (63-G) will trip the unit in the event of an oil surge.

2.2.2 Alarms. An alarm will be given in the control room for the following:

(i) operation of the gas element of the gas detector relay.

(ii) winding temperature.

(iii) low oil level.

2.3 Main Transformer Protection

2.3.1 Tripping

(MT1) The main protection for the main transformer is provided by relay (87). Note the zone of protection only covers the main generator, main transformer and main connections.

(MT2) Ground fault protection is provided by relay (64B). The relay is supplied from a current transformer whose primary is connected between the transformer HV neutral and ground. The relay will operate for a ground fault in the main transformer HV windings, the HV connections to the switchyard and the HV bus. Because this protection is not of the differential type, its operation will depend on the magnitude of the ground fault current and the setting applied to the relay.

(MT3) The gas detector relay (63G) will trip the unit in the event of an oil surge.

2.3.2 Alarms. The alarms for the main transformer are similar to those for the services transformer, ie,

(i) operation of the gas element of the gas detector relay.

(ii) winding temperature.

(iii) low oil level.

In addition, alarms are provided to warn of problems with the oil coolers.

2.4 HV Bus and Back-Up Tripping

(SY1) Differential protection (87) is used to protect the 230 kV HV bus, breakers and the connections as far as the transformer HV bushings.

(SY2) Differential protection (87D) is used to give overall back-up protection to the generator, main transformer and HV bus. The reason for this protection is to ensure the unit is safely shut down in the event of a failure of any of the individual protective relays or if any of the breakers fail to trip. Normally this protection is time delayed to give the other protections time to operate and complete their respective tripping functions.

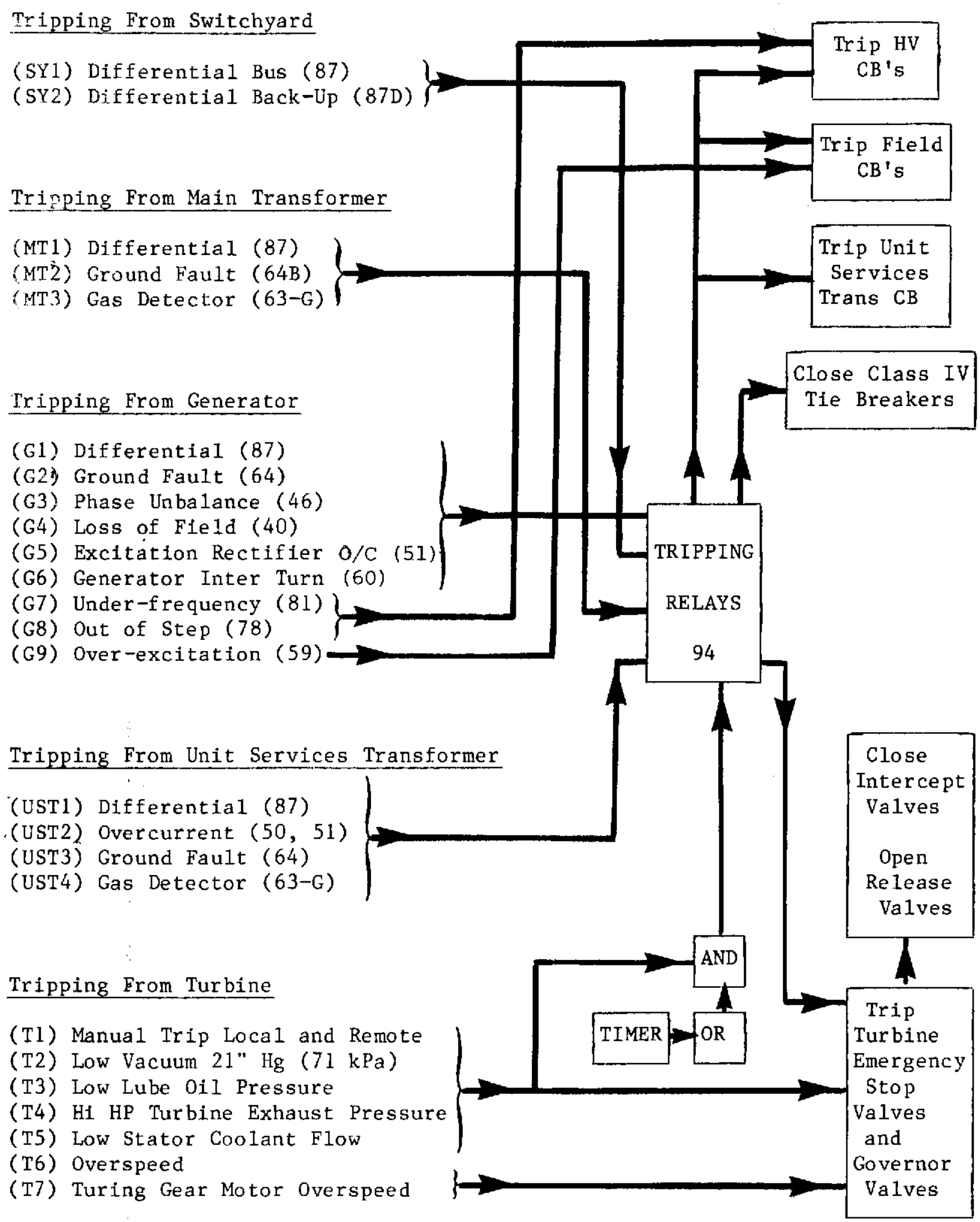

Figure 2: Block diagram showing the simplified tripping for a turbine generator and its associated circuits.

3.0 PROTECTION FOR THE COMPLETE TURBINE GENERATOR

3.1 Tripping

Figure 2 shows in block diagram form, the simplified tripping for a large turbine-generator and its associated circuits.

It must be understood that the information on Figures 1 and 2 is typical for a large turbine-generator. To ensure correctness of all details for a particular turbine-generator, it is necessary to study the tripping and control diagrams for that particular unit.

3.1.1 Points to Note on Figure 2

(a) With the exception of the underfrequency, out of step and over-excitation protections which only trip the HV breakers, the tripping from the electrical protection will trip the complete unit.

(b) The tripping from the turbine is divided into two sections:

(i) The first part consisting of trips 1-5 which trip the stop valves **directly.** The breakers are then **sequentially** tripped. This sequential tripping is only allowed after the emergency stop valves (ESV's) have all closed or a timer has operated. The reason for this sequential tripping is to ensure that the steam supply to the turbine has been shut off **and** the steam pressure in the turbine has fallen to a low value **before** the breakers are opened. Operating the ESV's in this manner minimizes the risk of overspeeding the turbine-generator which can occur when the HV breakers open and reject the load.

(ii) The second section consisting of trips 6 and 7 only close the ESV's. When these trips operate, it is assumed there is no electrical fault associated with the turbine-generator and therefore it is not necessary to operate the electrical protection. Under this condition, the turbine-generator remains connected to the system and "motors".

ASSIGNMENT

1. For the protection shown on the accompanying diagram, Figure A1:

   (a) State the name of each of the protective relays.

   (b) Briefly explain the protection given by each of the protective relays. State the "zone" covered by each relay.

   (c) State the breakers or other devices which are tripped by each of the protective relays.

2. For the protection and other devices given on Figure A2, show the tripping between the:

   (a) Protective relays and the tripping relays.

   (b) Tripping relays and the devices that are tripped (or closed).

   (c) Other protective relays or devices and the items they trip.

3. State and briefly explain the alarms associated with:

   (a) The generator.

   (b) Unit Services Transformer.

   (c) Main Transformer.

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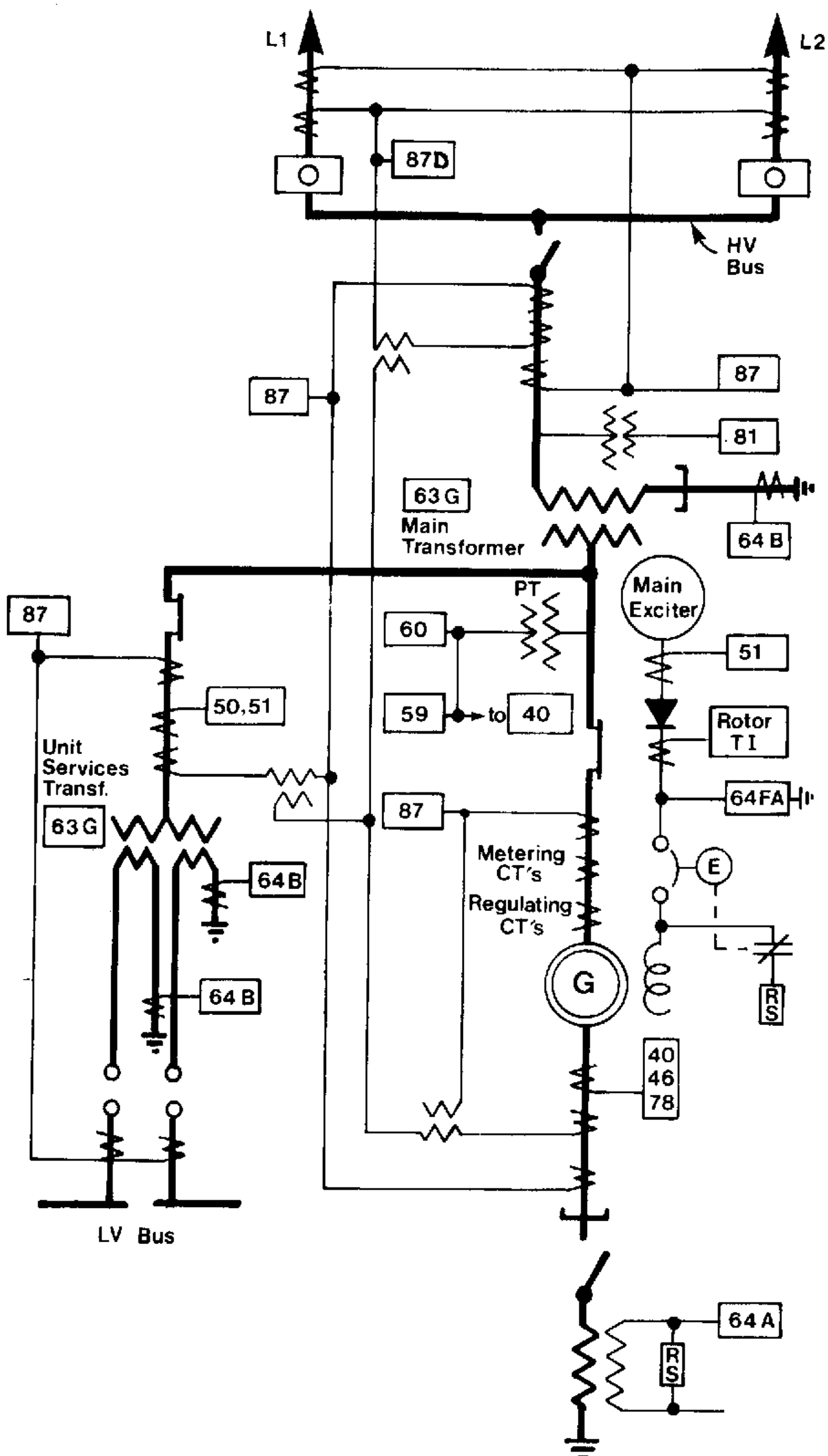

Figure A1: Simplified single line protection diagram for a turbine-generator.

Tripping From Switchyard

(SY1) Differential Bus (87)
(SY2) Differential Back-Up (87D)

Tripping From Main Transformer

(MT1) Differential (87)
(MT2) Ground Fault (64B)
(MT3) Gas Detector (63-G)

Tripping From Generator

(G1) Differential (87)
(G2) Ground Fault (64)
(G3) Phase Unbalance (46)
(G4) Loss of Field (40)
(G5) Excitation Rectifier O/C (51)
(G6) Generator Inter Turn (60)
(G7) Under-frequency (81)
(G8) Out of Step (78)
(G9) Over-excitation (59)

Tripping From Unit Services Transformer

(UST1) Differential (87)
(UST2) Overcurrent (50, 51)
(UST3) Ground Fault (64)
(UST4) Gas Detector (63-G)

Tripping From Turbine

(T1) Manual Trip Local and Remote
(T2) Low Vacuum 21" Hg (71 kPa)
(T3) Low Lube Oil Pressure
(T4) Hi HP Turbine Exhaust Pressure
(T5) Low Stator Coolant Flow
(T6) Overspeed
(T7) Turing Gear Motor Overspeed

TIMER

OR

AND

TRIPPING RELAYS 94

Trip HV CB's

Trip Field CB's

Trip Unit Services Trans CB

Close Class IV Tie Breakers

Close Intercept Valves

Open Release Valves

Trip Turbine Emergency Stop Valves and Governor Valves

Figure A2: Turbine-Generator Tripping.