ON-SITE ELECTRIC POWER SOURCE FACILITY FOR JAPANESE NUCLEAR POWER PLANT

T. Oohara
Nuclear Power Safety Information Research Center
Nuclear Power Engineering Test Center
Tokyo, Japan

Trends of construction of nuclear power plants in Japan, occurrence rate of incidents/failures of electric facilities, major example of incidents/failures, their countermeasure to prevent recurrence are introduced. Furthermore, safety administration system of the Government, electric utilities and manufacturers, and various countermeasures to prevent incident/failure of electrical facilities from the hardware and software sides are discussed.

I. Introduction

Nineteen years has been experienced on operation of nuclear power plant in Japan. Nuclear power plant under operation reached 30 units as of end of July, 1985. During this period, incidents or failures which caused trouble in electrical facilities were 33 cases.

The incidents/failures to be reported to the government are defined as follows : (1) Automatic shutdown (2) Unscheduled manual shutdown (3) Failure of reactor facilities which is found during periodical inspection and might cause trouble on reactor operation.

Utility companies are obliged to report such incidents/ failures to the government under the terms of the Law for Regulations of Nuclear Source Material, Nuclear Fuel Material, and Reactors and the Electric Utility Industry Law.

At the same time, Japanese Electric Utilities have their own duty to supply electricity by the Law and to respond such duty, utilities usually perform voluntary inspection and maintenance in addition to the periodical inspection and other activities required by regulations.

In the presentation, general trends and some practical example on incidents/failures of on-site electric power source failures are explained and discussed.

II. Experiences of On-site Electric Power Supply System for Japanese Nuclear Power Plant

In Japan, almost no incidents and failures for DC supply and emergency power supply equipments have been experienced in the past. In this presentation, therefore, operating experiences are introduced including plant power supply such as generator.

1. Trends of Troubles on Electric Power Supply Equipments in Japanese Nuclear Power Plant

1-1 Number of Nuclear Power Plants and Average Annual Number of Events on Electric Facility per Unit (Figure 1-1)

The initial commercial operations for GCR, BWR and PWR were 1966, 1969 and 1970, respectively, and the number of nuclear power plant has been increased since 1968, approximately 1.8 unit/year, and reached to 30 units as of end of July 1985.

The number of incidents and failures on electrical facility was slightly increased according to increase of nuclear power plant. However, the average annual number of events on electrical facility per unit decreased with some fluctuation and became less than 0.1 events/unit/year after 1977 as shown in Figure 1-1.

1-2 Number of Incidents and Failures Classified by Plant Facilities and by Electrical Facilities and Components (Figure 1-2)

The bar chart which is the left side of Figure 1-2 shows number of incidents and failures classified by facilities including reactor and turbine facility during the period of 1966 through 1983. Of the total incidents and failures, approximately 10% is attributed to electrical facility.

The breakdown of causes by facility is : Electrical transmission line (27%), generator (27%) instrumentation power supply (24%) and others. Except for the electrical transmission facility, whose trouble was caused by natural phenomena such as lightning strike, experiences on incidents/failures and improvements for generator facility and instrumentation power supply are explained in the following sections.

2. Safety Administration System (Table II)

(1) Improvement of regulatory system of the government

i) Permanent stay of an operation management specialist at each site.

ii) Mandatory inspection on the self-imposed security and administrations of the electric utilities once a year.

iii) Adoption of a qualification system for nuclear power plant operating supervisor.

iv) Establishment of the Nuclear Power Safety Information Research Center (NUSIRC) of the Nuclear Power Engineering Test Center aiming to effective use of operational information such as incidents and failures etc.

2 Improvement of the self-imposed security and administration system of electric utilities

i) Conclusive execution of quality control concerning to careful maintenance and repair work, etc.

ii) Development of technology represented by Upgrading and Standardization Plan for Light Water Reactor.

iii) Enhancement of education and training for the operators and maintenance personnel through the effective use of the operation and maintenance training center.

iv) Improvement of international and domestic information transmission and mutual information exchange of electric utilities through the Nuclear Information Center (NIC) of the Central Research Institute Electric Power Industry.

3 Agressive cooperation of manufactureres to electric utilities

i) Full cooperation of manufactureres to electric utilities for investigation of cause and counter-measures for incident and failure whenever it occures.

ii) Establishment of manufactureres' cooperation system for operation at each site.

3. Examples of Operating Experiences and Improvements

3-1 Historical Trend of On-site Bus Configuration (Figure 3-1)

As for BWR, examples of the on-site bus configuration of plants operated in early 1970's (on the left side) and that of recent plants after 1980 (right side) are shown in Figure 3-1.

Consolidation and reduplication of the start-up transformer and house transformer will be understood from the figure.

As for PWR, examples of the bus configuration is shown at the lower side of Figure 3-1. After 1990, a generator load breaker (G.L.B) will be installed. The new system reduces frequency of bus transfer and failure in bus transfer operation from house transformer to start-up transformer at start-up/shutdown or generator trip.

3-2 Modification on Control Circuit (Figure 3-2)

This is an example of incident which did not cause reactor scram but reduced plant output to about 87% from full power due to partial loss of off-site power source.

Loss of important power source for primary loop recirculation (PLR) pump speed control system occurred and a scoop tube of the fluid drive moved until the scoop tube blocking occurred and the reactor power decreased.

In this case, the duration of power loss was fortunately very short (2 second), but it has rather higher possibility of reactor scram for restartup of the power source.

The modification was made from this viewpoint that the power source for PLR control system is connected to the vital bus instead of normal instrument bus.

3-3 Improvement of Generator Field Regulator (Figure 3-3)

The next presentation is an example of incidents and failures and improvements regarding the generator. The major causes for generator trouble were excitor, especially the trouble on the contact between rotating and stationaly parts. One case is for excitation (70 R) slide resistor and others are related to brush and collector of excitor.

3-4 Example of Improvements of Vital Power Source Facility M-M-G Set (1) (Figure 3-4)

In this case, while switching operation to "Automatic" from "DC Operation" during startup after replacement of DC motor brushes, a changeover switch was over-rided to "OFF", consequently loss of power source occurred. The changeover switch was modified to two changeover switch with two position from one changeover switch with four position to prevent the recurrence.

3-5 Example of Improvements of Vital Power Source Facility M-M-G Set (2) (Figure 3-5)

During switching operation to the stand-by power source, M-M-G was mistakenly stopped before synchronization of vital power source, and it caused vital power source failure. An interlock was added to prevent recurrence of this kind of misoperation.

3-6 Example of Improvements of Vital Power Source Facility M-M-G Set (3) (Figure 3-6)

For BWR plant, M-M-G system was adopted in 1970's. Recently, as reliability of the static components have been improved, trend to adopt the static components became more apparant. In some existing plant, modification was limited to the extent as example 1 and 2. However, the static type facility is basically adopted in the new BWR plant and the static equipment has been used in PWR from the early plant.

3-7 Example of Reliability, Frequency of Periodical Test and Repair on Emergency Diesel Generator (Figure 3-7)

(1) Reliability (Start-up failure rate : 1.21×10^{-3}/ Demand)

On October 1984, 27 nuclear power plants were operating with 55 diesel generators. By this time, 18 cases of start-up failures out of 14,878 times of start-up test.

On the first half of 1970's, troubles occurred due to low lubricating oil pressure and misadjustment of governor etc. Recently, the reliability has been improved as follows:

a) Period of investigation
   Fiscal year 1970 through 1983

b) Definition of start-up failure
   i) Diesel generator could not start on start-up test
   ii) Diesel generator automatically tripped by actuation of the protection system after started on start-up test.

c) Results of investigation
   i) Total number of start-up 14,878
   ii) Number of start-up failures 18
   iii) Start-up failure rate of emergency diesel generator

$$P = \frac{18}{14,878} \doteqdot 1.21 \times 10^{-3}/\text{Demand}$$

Recently, the start-up failure rate decreased to 1.49×10^{-4}/Demand after 1980. The main factors for such improvement are:

i) Reliability of the emergency diesel generator was improved.

ii) Improvement of maintenance/repair of the generator facility.

iii) Enforcement of safety administration system including operation management specialist system

1 Start-up failure rate during fiscal years 1970 through the end of 1979.

$$P = \frac{17}{8,184} \doteqdot 2.08 \times 10^{-3}/\text{Demand}$$

2 Start-up failure rate during fiscal years 1980 through the end of 1983.

$$P = \frac{1}{6,694} \doteqdot 1.49 \times 10^{-4}/\text{Demand}$$

(2) Frequency of Periodical Test

The Safety Regulation is defined to perform periodical test of diesel generator once a month. But some of electric utilities usually performs voluntary inspection as follows:

1 Three times of no load tests for each diesel generator for every month.

2 A load test for each diesel generator for every month.

(3) Examples of Repair (2 cases)

Two examples of repair are shown as follows:

1 Capacitor in the generator synchronizing circuit damaged due to burn out. The capacitor, of which the withstand voltage is improved, was replaced.

2 Air leakage occurred from the fitting part of a root valve of start-up air pressure detector. The fitting part was modified to welding type from screw type.

4. Conclusion

4-1 Improvement of Hardware (Figure 3-1 through 3-7)

4-2 Upgrading of Software

Enhancement of training

1 BWR Training Center (BTC), Nuclear Power Training Center (NTC)

  i) Standard Operator Training Course
  ii) Operator Re-training Course
  iii) Advanced Operator Training Course
  iv) Family Training Course

2 Nuclear Power Plant Training Center

  i) CRD exchange work
  ii) Welding work
  iii) Refueling floor work

4-3 Conclusive Execution of Countermeasure to Prevent Recurrence

As previously mentioned it is respectedly emphasize that "Conclusive execution of investigation of causes and countermeasures to prevent recurrence of incidents and failures" is the most important factor.

When incident or failure occurred, the government, electric utilities and manufacturereres cooperate each other to conclusively execute investigation of causes and countermeasures to prevent recurrence of the incident or failure.

Furthermore preventive maintenance and repair are effectively taken through the intimate information exchange between electric utility and manufacturereres.

Those execution explained above are believed to be main factore reduced incidents and failures in Japan.

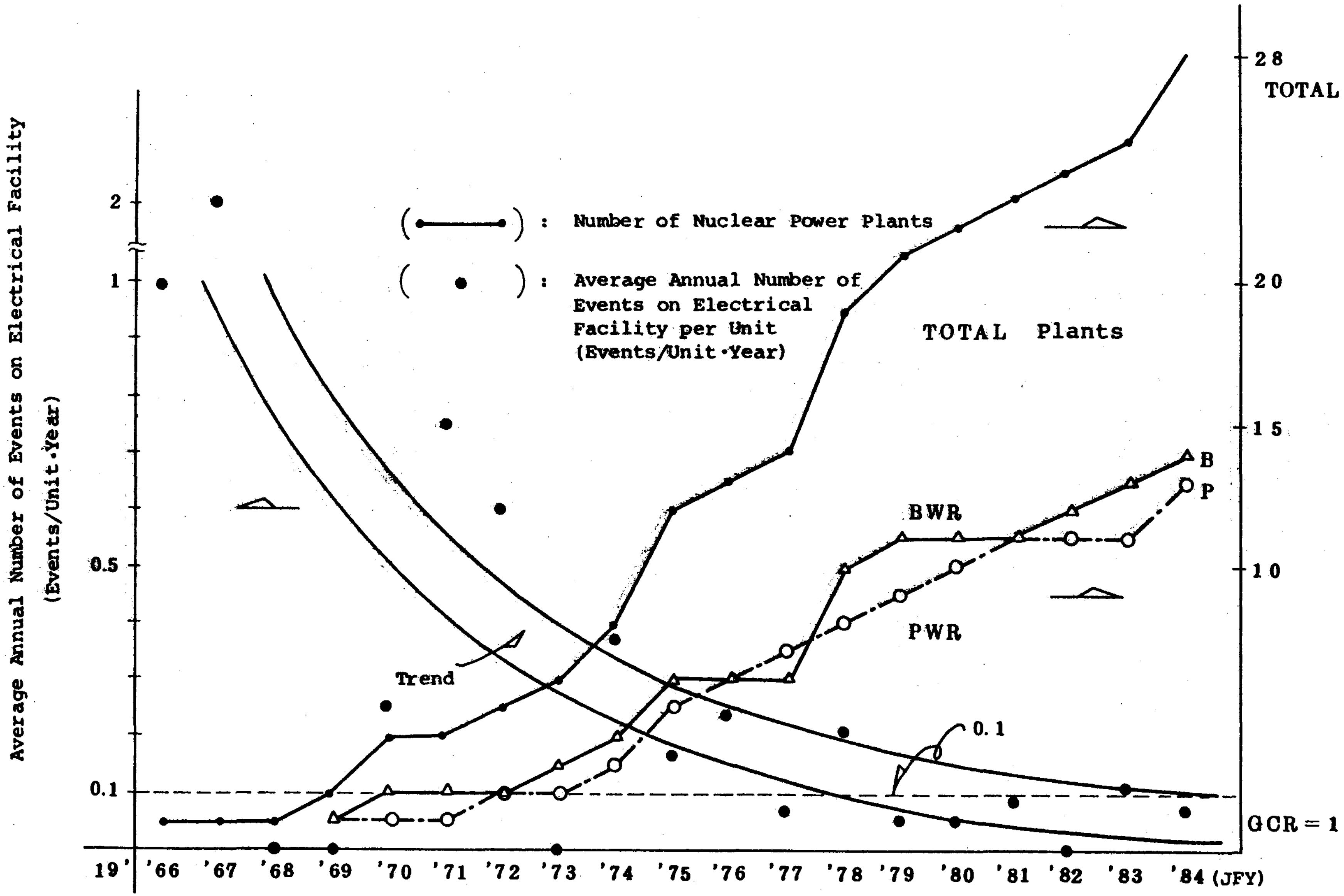


Figure 1-1 Number of Nuclear Power Plants and Average Annual Number of Events on Electrical Facility per Unit

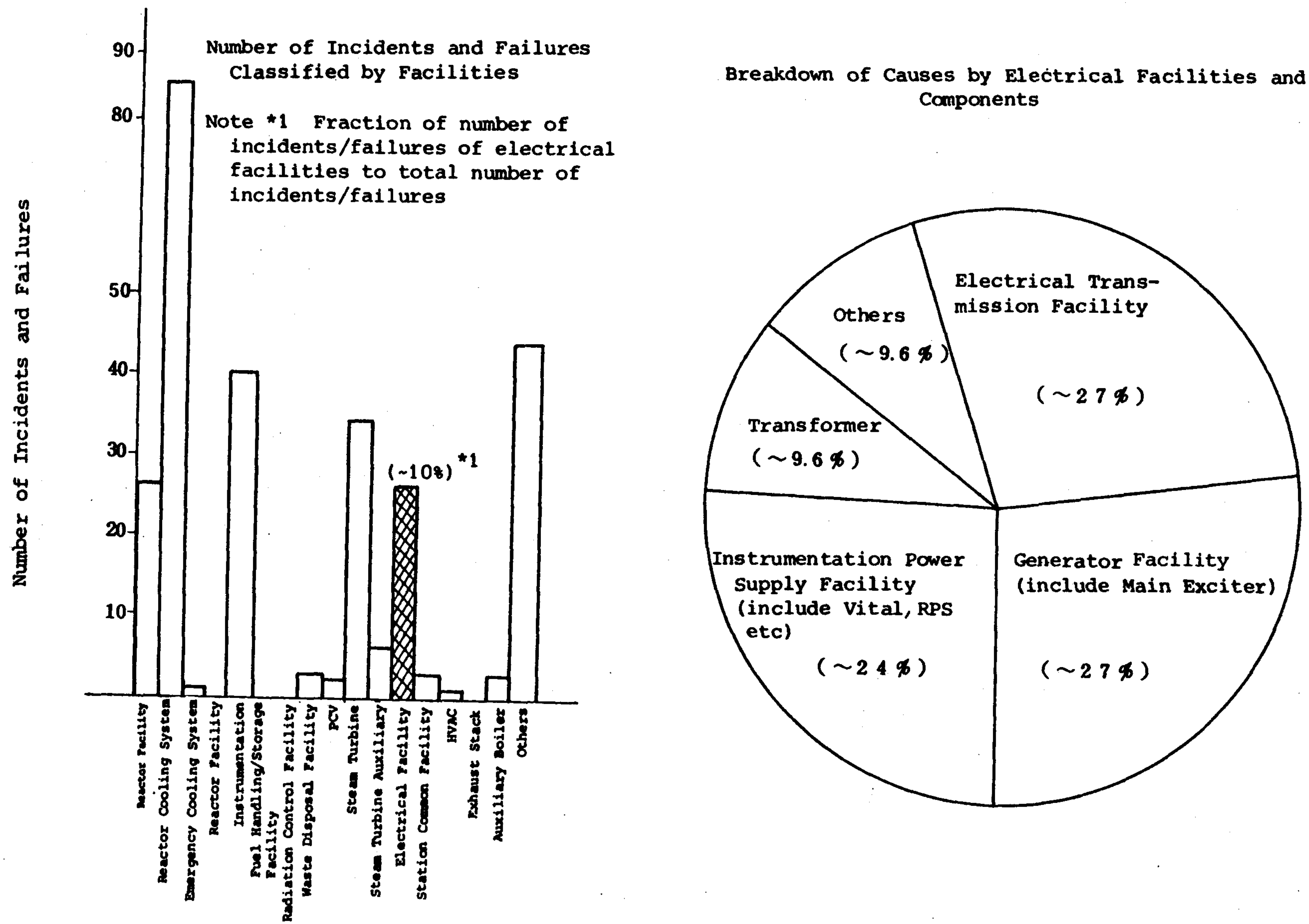


Figure 1-2 Number of Incidents and Failures Classified by Facilities and by Electrical Facilities and Components

Table II. Safety Administration System

1 Improvement of administration system of the government

i) Permanent residence of an operation management specialist at each site.

ii) Mandatory inspection on the self-imposed security and administrations of the electric utilities.

iii) Adoption of a qualification system for nuclear power plant operating supervisor.

iv) Establishment of the Nuclear Power Safety Information Research Center (NUSIRC) of the Nuclear Power Engineering Test Center aims to effective of operational information such as incidents and failures etc.

2 Improvement of the self-imposed security and administration system of electric utilities

i) Conclusive execution of quality control concerning to careful maintenance and repair work etc.

ii) Development of technology represented by upgrading and Standardization Plan for Light Water Reactor.

iii) Enhancement of education and training for the operators and maintenance personnel through the effective use of the operation and maintenance training center.

iv) Improvement of international and domestic information transmission and mutual information exchange of electrical utilities through the Nuclear Information Center (NIC) of the Central Research Institute Electric Power Industry.

3 All aspect cooperation of manufactureres with electric utilities

i) Full cooperation of manufactureres to electric utilities for investigation of cause and countermeasure for incident and failure whenever it occurred.

ii) Establishment of manufactureres cooperation system for operation at each site.

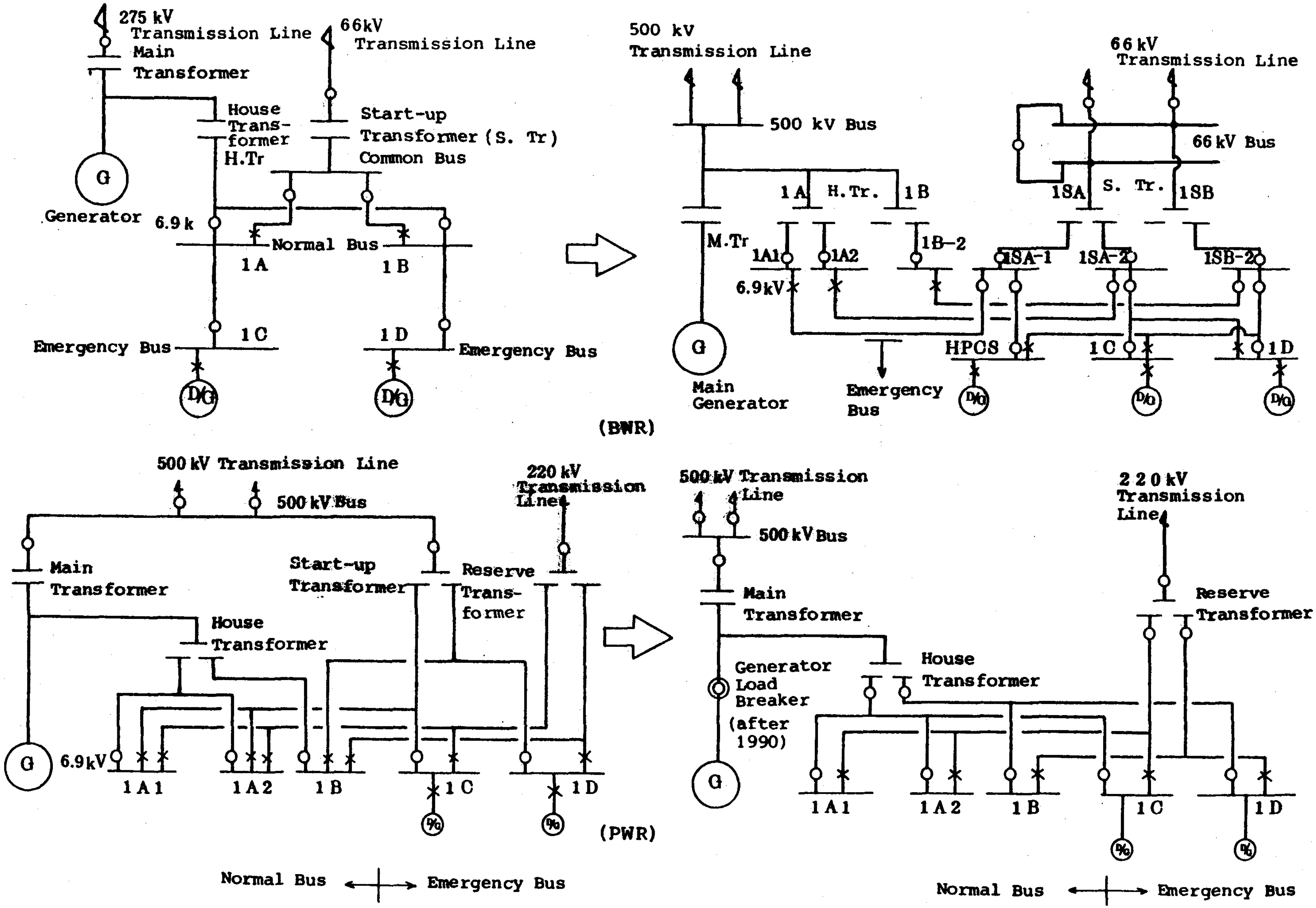
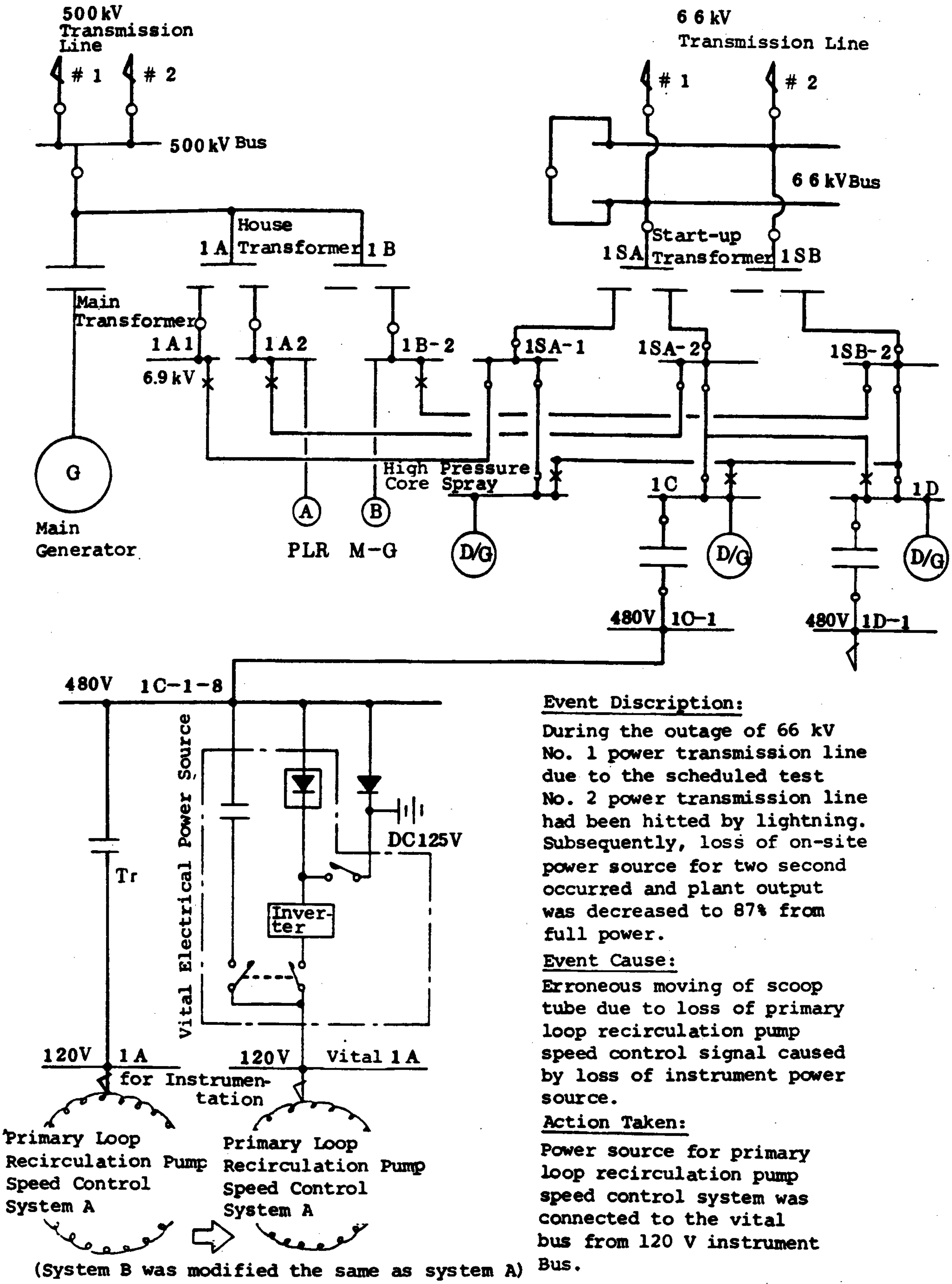


Figure 3-1 Historical Trend of On-site Bus Configuration



Event Discription:
During the outage of 66 kV No. 1 power transmission line due to the scheduled test No. 2 power transmission line had been hitted by lightning. Subsequently, loss of on-site power source for two second occurred and plant output was decreased to 87% from full power.

Event Cause:
Erroneous moving of scoop tube due to loss of primary loop recirculation pump speed control signal caused by loss of instrument power source.

Action Taken:
Power source for primary loop recirculation pump speed control system was connected to the vital bus from 120 V instrument Bus.

Figure 3-2 Modification on Control Circuit

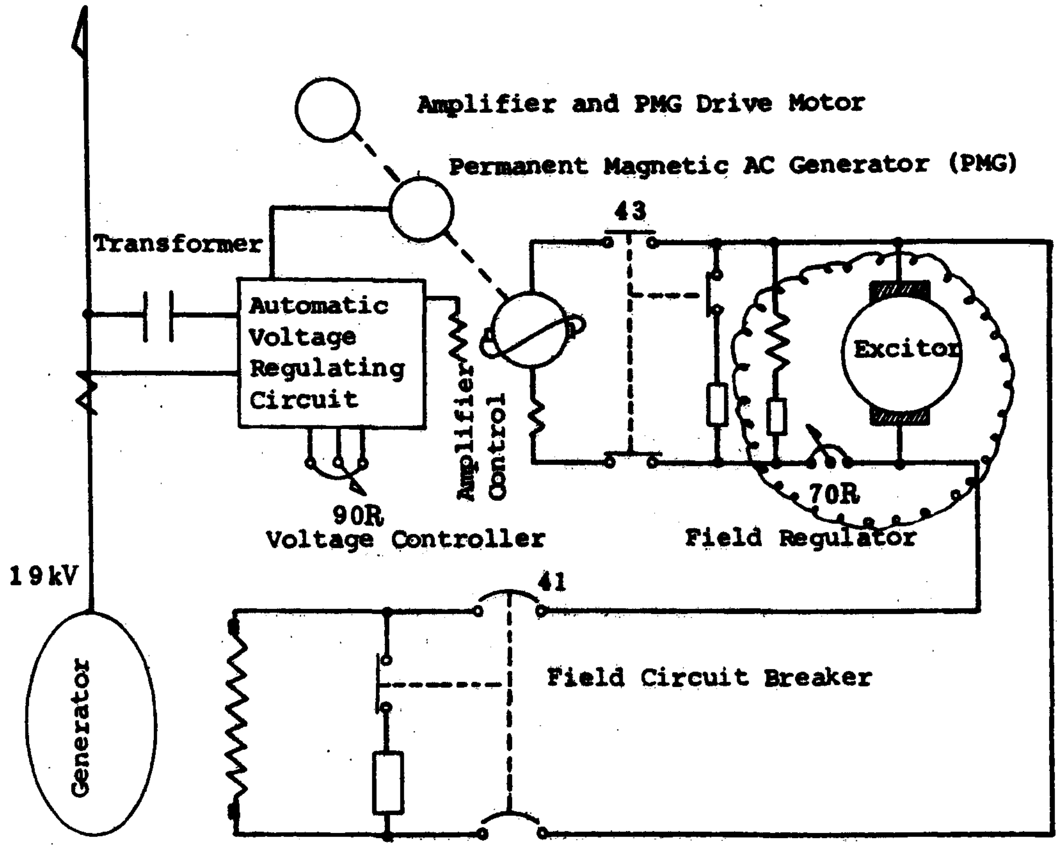
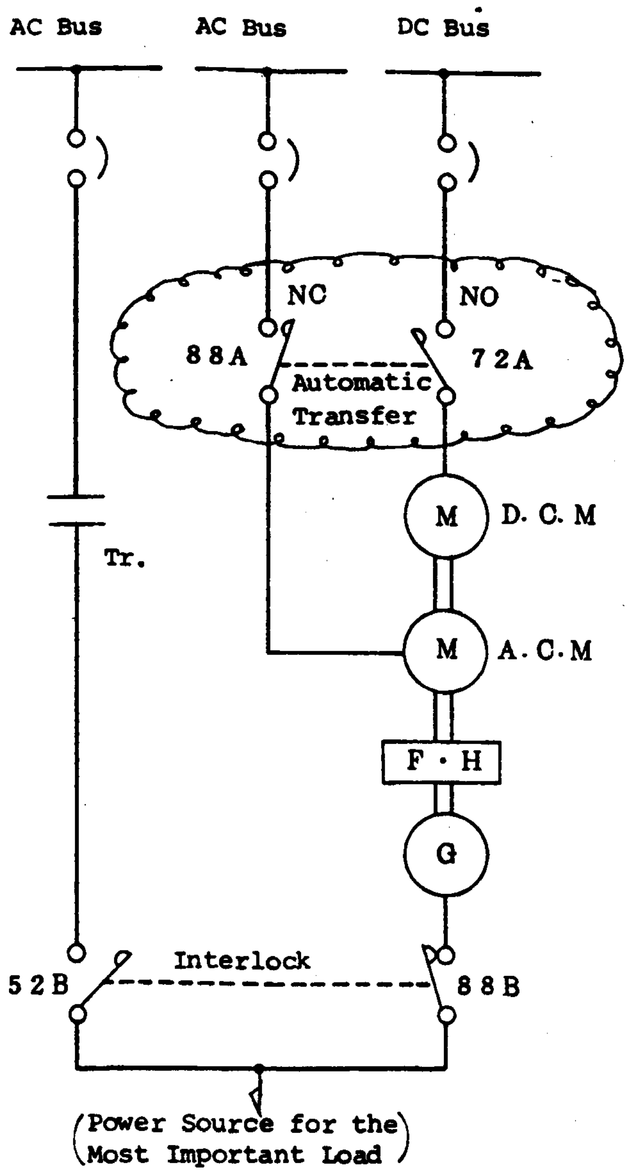


Figure 3-3 Improvement of Generator Field Regulator

No.	Event Description	Event Cause	Action Taken
1	Arc occurred at the gap between brush and brush holder of excitation (70 R) slide resistor	o Too narrow of the gap o Adherence of dust to the gap	o Gap between brush and brush holder was modified to 0.3 mm from 0.1 mm o Installation of cover for dust proof
2	Spark occurred at the gap between brush and collector. Subsequently, it flushed over. (Trend : Brushless type will be adopted, and it had been used at thermal power plant)	o Defective performance of brush spring o Insufficient confirmation on wear of brushes	o Replacement of brush and holder o Brush and brush holder was changed to cartridge type in order to easily perform inspection and maintenance o All brushes were painted yellow stripes in order to confirm on wear of brushes.



Event Description:

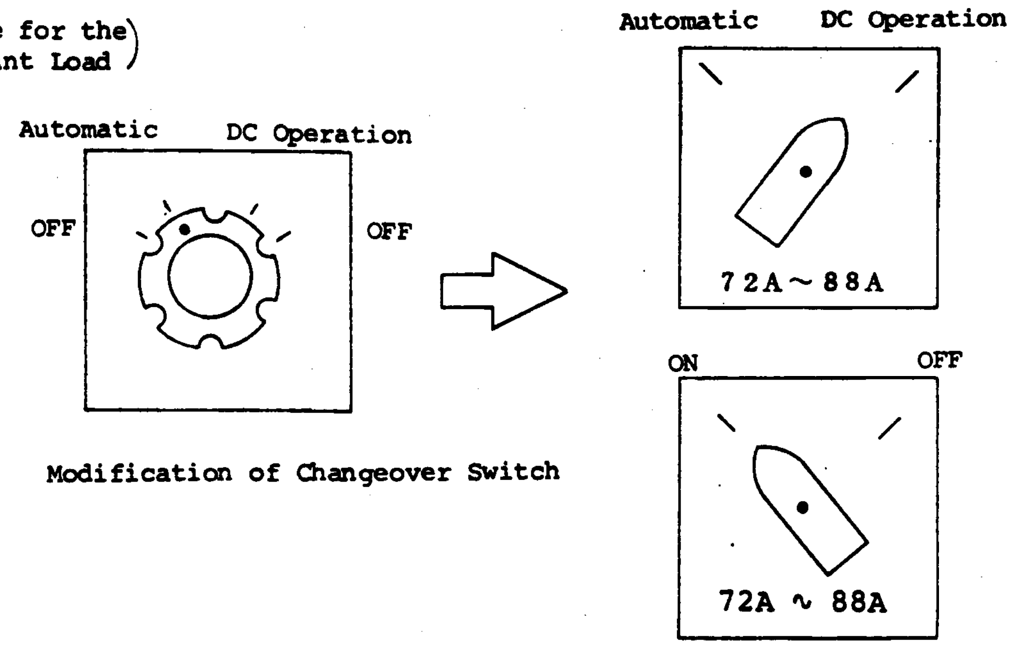
While switching operation to "A.C. Operation" (automatic) from "D.C Operation" during restart-up after replacement of D.C motor bushes, loss of vital power source occurred.

Event Cause:

Misoperation of a changeover switch (switch over-ride)

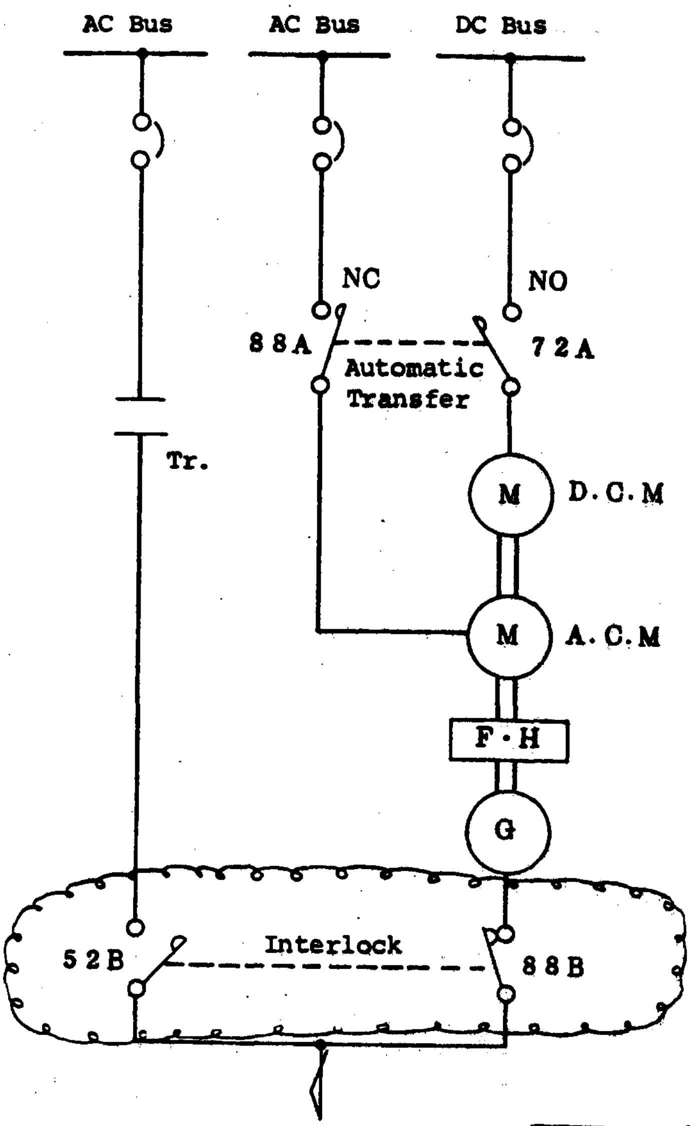
Action Taken:

The changeover switch was modified to two changeover switches with two position from one changeover switch with four position.



Modification of Changeover Switch

Figure 3-4 Example of Improvement of Vital Power Source Facility (1)



Event Description:

During switching operation to the AC bus from M-M-G, loss of vital power source occurred due to fail of synchronization.

Event Cause:

88B was opened before 52B was closed.

Action Taken:

Interlock was added as follows.

Addition of Interlock

(Power Source for the Most Important Load)

- o Feedwater control
- o EHC Control
- o Radiation Monitoring
- o Indication of Isoration Valves
- o Computor
- o In-Core Monitor

etc.

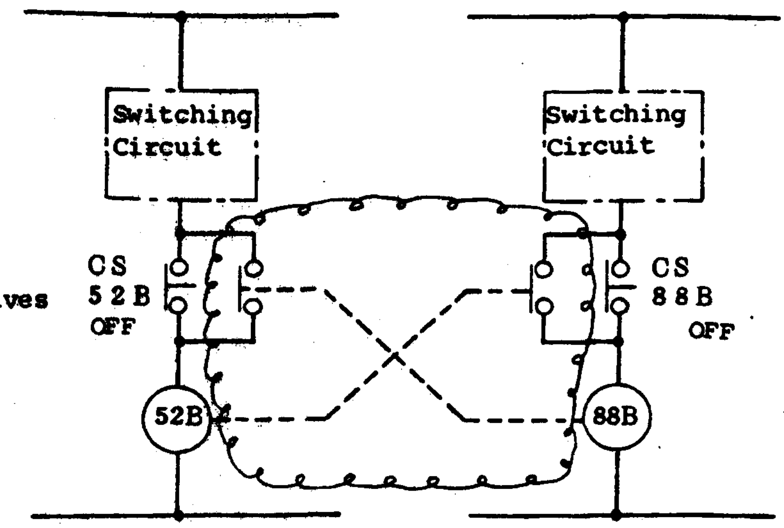


Figure 3-5 Examples of Improvements of Vital Power Source Facility (2)

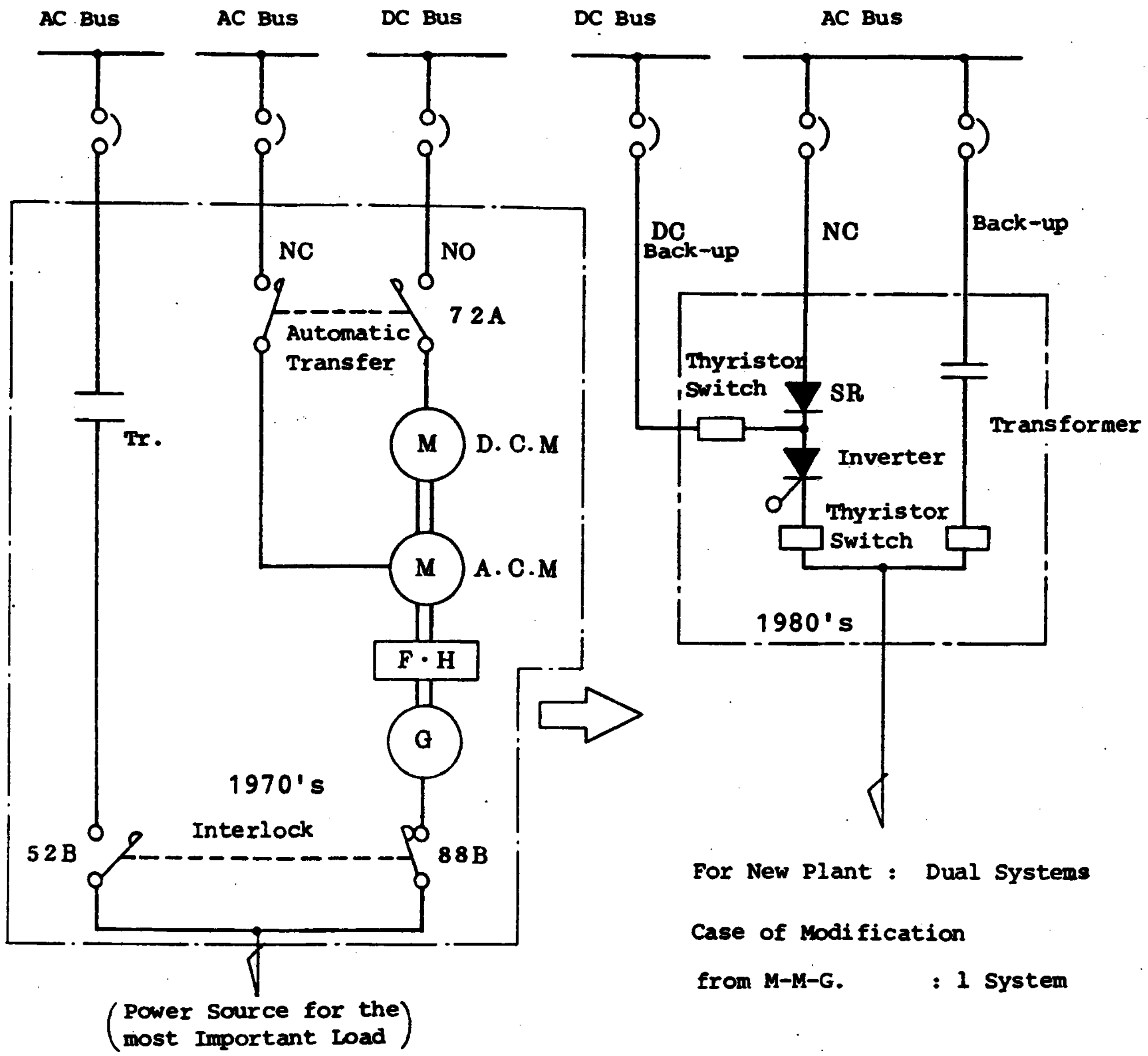


Figure 3-6 Example of Improvement of Vital Power Source Facility (3)

(1) Reactor trip due to loss of vital power source forms about 25% of the incidents and failures due to electrical causes. In 1970's plant, improvement and/or modification to the static equipment (one system in general) has been performing.

(2) In 1980's plant, the static equipment (dual systems) has been adopted from design stage.

Reliability, Test and Repair on Emergency Diesel Generator

(1) Reliability (Start-up failure rate : 1.21×10^{-3})

On October 1984, 27 nuclear power plants were operating with 55 diesel generators. By this time, 18 cases of start-up failures out of 14,878 times of start-up test.

On the first half of 1970's, troubles occurred due to low lubricating oil pressure and misadjustment of governor, etc. Recently, the reliability has been improved as follows:

(i) During fiscal years 1970 through the end of 1979 : 2.08×10^{-3}/Demand

(ii) During fiscal years 1980 through the end of 1983 : 1.49×10^{-4}/Demand

(2) Frequency of Periodical Test

(i) Three times of no load tests for each diesel generator for every month.

(ii) A load test for each diesel generator for every month

(3) Examples of Repair for Diesel Generator Facilities

(i) Example 1

Event description : Capacitor in the generator synchronizing circuit damaged due to burn out.

Action taken : The withstand voltage of the replaced capacitor was modified to DC 1,260 V from 630 V.

(ii) Example 2

Event description : Air leakage occurred from the fitting part of a root valve of start-up air pressure detector.

Action taken : The fitting part was modified to welding type from screw type.

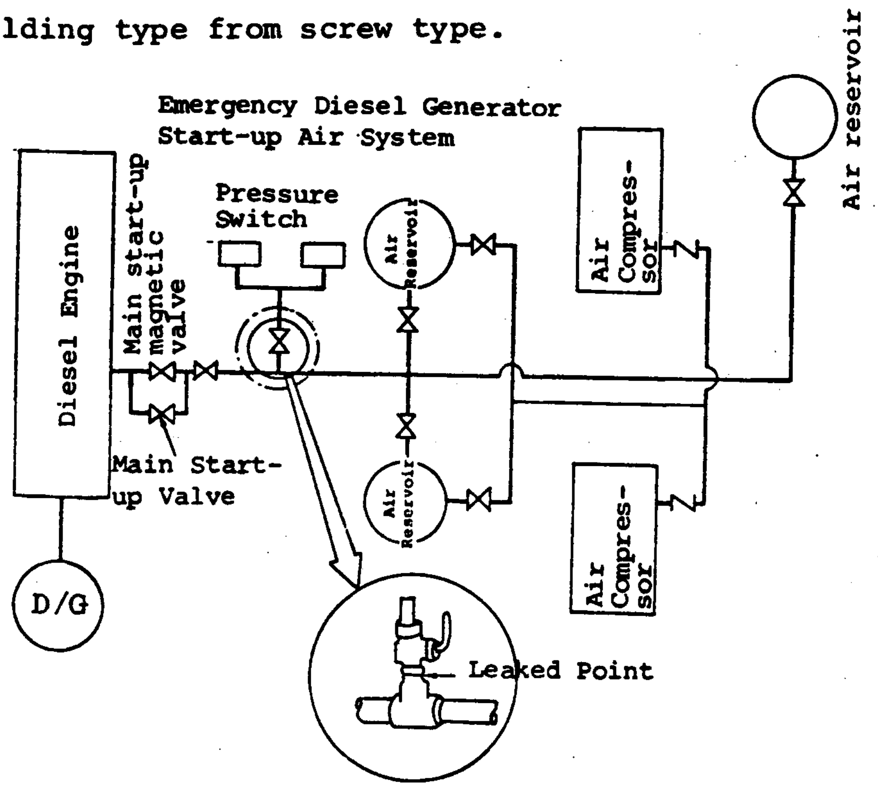


Figure 3-7 Repair on Emergency Diesel Generator

Table 4. Summary

I. Improvement of hardware

- (i) Temporary countermeasure
- (ii) Eternal countermeasure
- (iii) Design change

II. Upgrading of software

Enhancement of training

BTC, NTC

- (i) Standard Operator Training Course
- (ii) Operator Retraining Course
- (iii) Advanced Operator Training Course
- (iv) Family Training Course

Nuclear Power Plant Training Center (for maintenance)

- (i) CRD exchange work
- (ii) Welding work
- (iii) Refueling floor work

III. Countermeasure to prevent recurrence !!

- (i) Hardware
- (ii) Software