LOAD DESPATCH TECHNIQUES
(APPLIED TO KARNATAKA AND SOUTHERN REGIONAL POWER SYSTEMS)

A DISSERTATION
submitted in partial fulfilment of the
requirements for the award of the Degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

By
B. CHIKKA KALAPPA

WATER RESOURCES DEVELOPMENT TRAINING CENTRE
UNIVERSITY OF ROORKEE
ROORKEE U.P. (INDIA)
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C E R T I F I C A T E

Certified that the dissertation entitled "Load Despatch Techniques, (Applied to Karnataka and Southern Regional Power Systems)", which is being submitted by Shri B. Chikka Kalappa in partial fulfilment for the degree of Master of Engineering in Water Resources Development, University of Roorkee, Roorkee is a record of candidate's own work carried out by him under my guidance and supervision. He has worked more than 9 months for preparing the dissertation.

This is further to certify that the matter embodied in this dissertation has not been submitted for the award of any other degree or diploma.

(Brijesh Chandra)
Reader, (Elect. Eng.)
Water Resources Development
Training Centre,
University of Roorkee,
Roorkee.

Roorkee
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B. Chikkakalappa

(B. Chikka Kalappa)

SYNOPSIS

Integrated operation of power systems in each State or area with those of neighbouring States/ areas is essential for optimum utilisation of power plants economically and advantageously. Systematic efforts have been made during the last decade to unify the power systems of the country on a regional basis. The first regional power grid that has already gone into operation is the southern grid comprising of Karnataka, Andhra Pradesh, Kerala and Tamil Nadu and the Union territory of Pondichery.

For coordinating and monitoring the operations of an integrated power systems, on the concept of coordinated (i.e. integrated) basis, with a view to realising the various benefits inherent in such operation, establishment of load despatching stations are required.

For satisfactory operation of the inter-connected systems, the two variables namely load and frequency have to be regulated. The governor of the prime mover plays an important part in the control of system frequency and load. Further power systems are inter-connected for purpose economy interchange and reduction reserve capacity. Tie line load bias control is very useful (in regulation of frequency) for coordinated operation of power systems, as it provides a convenient means for differentiating the responsibility for the system load changes. Further in interconnected systems the incremental cost of received power should be same from all sources for optimum economy. Incremental slide rules, penalty factor computers etc. are used for scheduling of generation for optimum economy. Computer controllers are best suited for controlling simultaneously the system frequency, net interchange of power and economical allocation of generation.

Communication facilities generally required for power system operation comprise telephony, telemetering, tele-signalling, remote control and teleprinting. The supply utilities in India have relied largely on P.L.C.C. facilities for the above purposes. The despatching stations shall be located such that P.L.C.C. facilities are available to all parts of the network. It is also desirable to utilise P & T facilities fully alongwith P.L.C.C. for obtaining 100% reliable communication.

The integrated operation of the southern regional grid has helped to tide over a number of emergencies thus improving the reliability of power systems in a significant manner. The installed capacity of the region by the end of V Plan will be of order of 8973 Mw comprising 6121 Mw Hydro and 2852 Mw Thermal. Tremendous load growth is also anticipated in the region. It is necessary to establish number of inter-state lines of adequate capacity for operation of the region on integrated basis. More economical and technical benefits will accrue to the region by adopting sophisticated methods of load despatch techniques.

CHAPTER -1

INTRODUCTION

1.1 The power systems in the country in the early years of development were simple with most of the load centres being fed by the generating stations over radial lines. Unified grid systems interconnecting number of hydro, thermal and nuclear power stations and extending over large areas have now developed.

Grid development on the basis of the small area or States alone is not enough. It is now well recognised all over the world that power development in isolation is not possible. Contiguous power systems have got to be interconnected and regionwise integration has to be attempted in every country for realising the various technical and economic advantages inherent in such operation. Interconnection of power systems provide a way to share generation reserves and thereby avail sub-stantial savings in both capital cost and running cost. Thus the concept of power pool is introduced for joint operation of independent utilites so that the effective reserve of each one increases.

Power pools not only permit sharing of generation reserves but also encourages inter-change of economy energy. The original concept considered such inter-change was only during off peak periods. But now the time zone effect which gives non-coincident system and pool peaks is being more consideration.

1.2 The advantages of integrated operation of power systems (between states) are low installed capacity, bigger unit size additions, reduced spinning reserve requirements, minimum generation cost and additional operating benefits. Apart from these advantages obtained by interconnection and integrated operation, the power supply reliability and quality are improved which have greater effect on industrial growth and human living.

1.3 United Kingdom and France provide excellent examples of completely integrated power systems. While these countries are comparatively small, U.S.S.R. is the largest country in the world where systematic efforts are being made to develop one interconnected system for the entire country. In Europe many of the countries are now interconnected. The most striking examples of coordinated operation of power systems transcending national frontiers are the pools of U.C.P.T.E., S.U.D.E.L., etc. in Europe. The U.C.P.T.E., in particular covers eight countries of Western Europe and various pools are inturn connected to form the vast European power pool.

1.4 The concept of integrated operation of contiguous power systems is now fully recognised in India and systematic efforts are being made to unify the power systems on a regional basis. The subject of planning and establishment of regional grids was discussed in the seminars arranged by C.B.I. and P. Following the recommendations at these Seminars a high level committee comprising the representativies of the C.W. & P.C., Planning Commission and State Electricity Boards etc. was appointed to examine the scope of formation of regional grids. On their recommendations the country was divided into the following five regions.

Northern Region:	Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Uttar Pradesh, Rajasthan and the Union territories of Delhi and Chandigarh.
Western Region :	Gujarat, Maharashtra, Madya Pradesh and Union territory of Goa Daman and Diu.
Southern Region:	Andhra Pradesh, Tamil Nadu, Karnataka, Kerala and Union territory of Pondichery.
Eastern Region :	West Bengal, Bihar, Orrissa and Damodar Valley Corporation.
North Eastern Region :	Assam, Manipur, Tripura, Nagaland, Meghalaya and the Union territories of Arunachal Pradesh and Mizoram.

Figure 1.1 shows the formation of regions in the country.'

1.5 For deriving the maximum benefit of integrated operation of power systems, the generation and transmission facilities within each region being planned as a region as a whole. Thus it would be clear that a stage would be reached when the constituent power systems in the region will be interconnected with strong and free flowing tie lines to operate the region on one system basis (i.e. Regional grid).

1.6 When more and more power stations are connected together it becomes difficult to control the various operations of the interconnected network. To overcome the difficulty of operating such a network on a coordinated basis establishment of a central control and coordinating station becomes necessary. Such a station is called "Load Despatching Station".

The technique of scheduling, coordinating and monitoring the operations of an integrated power system, on the concept of coordinated (i.e. integrated) basis, with a view to realising the various benefits inherent in such operation may defined as "Load Despatching".

1.7 A load despatching station controlling a State power grid and that controlling a regional power grid are called state load despatching station (SLDS) and Regional load despatching station (RLDS) respectively. A load despatching station controlling the National power grid is called as National load despatching station (NLDS).

1.8 The main objectives of load despatching are as follows:

i) To satisfy load requirements on a continuous basis from the stand point of magnitude (MW). Frequency and voltage.

ii) To minimise the generation cost over a specified period of time consistent with system security.

iii) To limit duration and extent of repercussions due to faults and restore normal functioning of the network with utmost rapidity.

iv) To collect accurate operating records.

The methods adopted to achieve the above objectives for efficient power system operations are known as "Load Despatch Techniques".

The various techniques adopted in power systems to achieve the above objectives are dealt in detail in subsequent chapters, with special reference to Karnataka and Southern regional power systems.

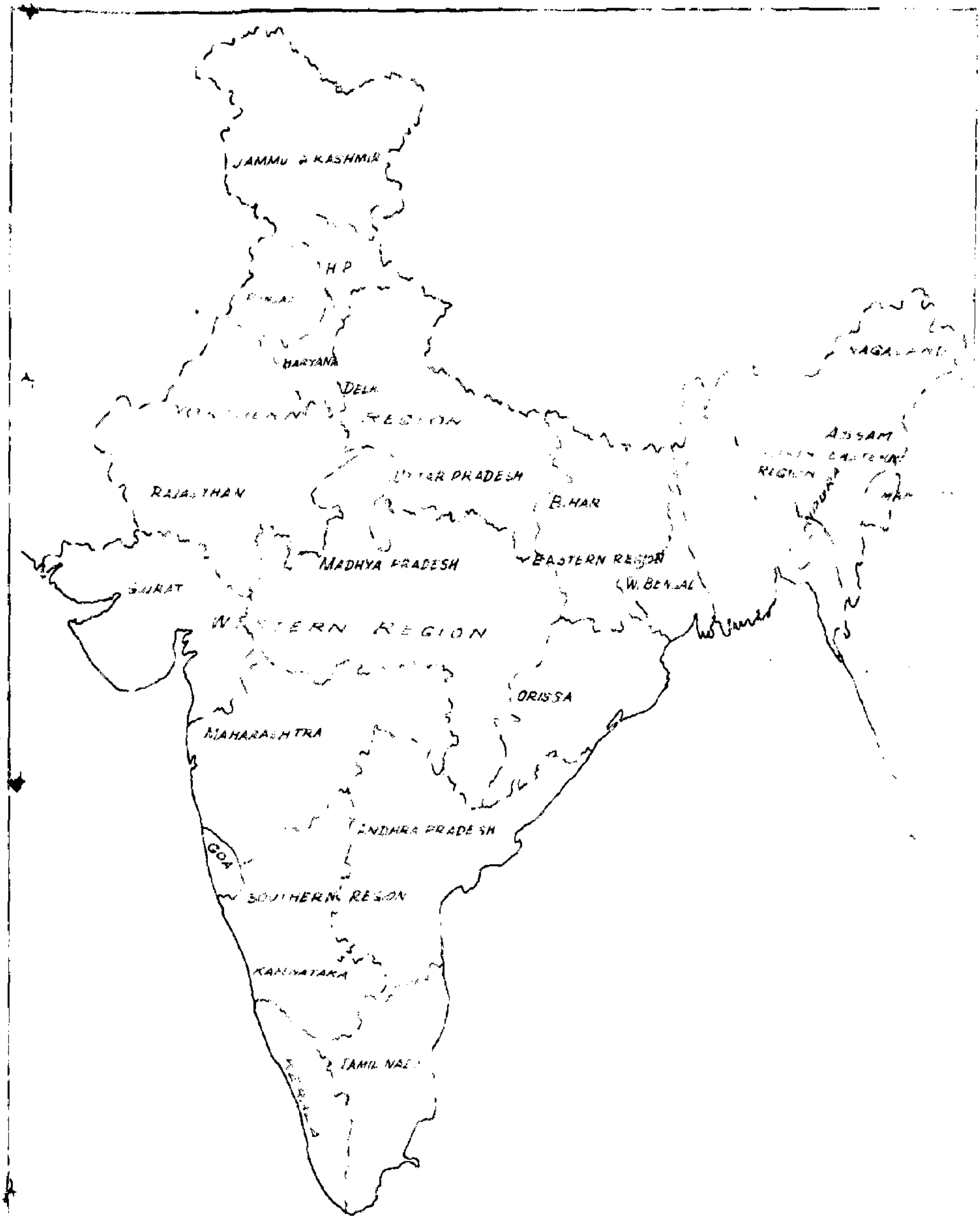


FIG. 1 GRID MAP OF INDIA SHOWING FORMATION OF REGION

CHAPTER - 2

SYSTEM DESPATCH AND CONTROL

2.1 Achievement of basic objectives of system despatch and control as stated earlier involves the following.

1. Operational planning.
2. Operational control.
3. Operational accounting and review.

2.2 Operational planning:

2.2.1 The requirement of operational planning involves making calculations to decide how to operate the system in the next hour, day, week or month. The planning part of the system operation has gradually become very important due to operation of the system with increasing number of interconnections and the possibilities of savings through interchanges with the neighbouring systems.

The following functions come under the purview of the operational planning.[1]

1. Load forecasting.
2. Maintenance Scheduling.
3. Spinning Reserve Determination.
4. Unit participation programme.
5. Evaluation of tie line flows.
6. Fuel Selections.
7. Reservoir Management and
8. Hydro Thermal generation coordination.

2.2.2 Load Forecasting:

Load forecasting is the key part of the operational planning and all other functions listed above are based on this. The load forecasts are two fold. Firstly, the long term load forecast to enable each system to plan construction of power stations, transmission lines and grid sub-stations so that power is available to the consumer when he needs it. Secondly, the short term forecasts on the basis of which the system operator/chief load despatcher decides how to meet the load by operating the system most economically The load forecasts and scheduling of generating plants to meet the loads are prepared on annual, weekly and daily basis. The daily schedules shall be prepared, one day in advance. The forecasts should be made as accurately as possible with reference to load curves of the previous day, the corresponding day in the previous week and year, after making suitable allowance for the load growth during the course of the year and the latest weather forecast. Due allowance should also be made for special events if any for the day. Forecasting errors should be held within a close range so that the distribution of load on various generating stations can be done in most econoic manner.

A record of all variations from the anticipated load that occur in practice should be maintained and the various causes for the variations shall be analysed by the load despatching office with a view of improving the techniques of forecasting in a systematic manner.

2.2.3 Maintenance Scheduling:

Maintenance schedule involves coordination of planned outages of both the transmission system and the generating units. While doing this two basic points must be kept in mind. One is the system reliability and the other is the production cost. Since the size of turbo-generator units are on the increase (in U.S.A. generating sets above 1100 MW[1]. are already in operation and in India the largest generating set rated at 215 MW is under operation at Rana Pratap Sagar Atomic Power Station), one of the primary objectives during the planning and of the maintenance schedules is the economics of the production cost. This is done by comparing the increased sale of energy if a machine or transmission line can be over hauled quicker by paying overtime wages to the maintenance personnel with the increased energy cost due to the operation of uneconomic units or by import of energy at a higher cost and in extreme cases by resorting to load shedding. Due to the critical evaluation of maintenance schedules, reduced production cost and improved system reliability would result.

2.2.4 Spinning reserve.

Spinning reserve determination and unit commitment mainly come under short range planning for reliable system operation. It provides regulating capacity which covered forced outages of generating plant and errors in estimating the load demands. The quantum of reserve depends upon the load level. Seasonal and daily variations in load, number and size of generating units, forced outage rates of sets, characteristics of the generating plants, limitations of the plant capacity and the desired standard of reliability.

In large interconnected systems in U.S.A. spinning reserve of order of 6 % of the peak demand is usually maintained. In the central Electricity Generating Board of U.K. the spinning reserve maintained at a given time is around 5% of the peak demand, whereas in the French system which has a mixed hydro-Thermal character, a spinning reserve of about 4%(2) is usually maintained. In case of Hydro & Thermal systems the spinning reserve capacity is readily available from storage hydro plants in conjunction with the thermal reserve.

2.2.5 Unit participation programme:

Unit participation programme helps the load despatcher to decide which machines should be operated and when a machine or machines shall be connected or disconnected from the system. The programme evaluates the total production cost by calculating the fuel cost. The cost of start-up and the cost of shutting down, if any for various combinations of machine to minimise the total production cost. The despatcher shall have the over-all unit start up and shut down schedules of all units. The following points must be considered

- capacity to meet the load requirements
- unit availability
- operating costs
- system constraints
- contractual constraints.

2.2.6 Evaluation of Tie Line Flows:

Evaluation of tie line flows is done for hourly exchanges and daily exchanges. The daily interchanges in a particular tie line require proper evaluation so that over a period (usually one month) the total energy exchanged remains as near the schedule as practicable. The hourly exchanges between the two power systems are usually negotiated by the respective load despatchers, to minimise the production cost of any system at that time of importing power, instead of bringing un-economical machine on bar. It is usual in an interconnection to share equally the differences in the incremental cost of generation of the two systems ruling at the begining of the hour.

The load despatcher would require very accurate information pertaining to the proposed interchange of power to enable him to take correct economic decisions and meet the contractual obligations. For integrated operation of different power systems the most economic condition occurs when the incremental costs on either side of the tie point are equal[3].

The implementation of new concepts of and the technique of computers enable the proposed interconnected transactions to be evaluated very rapidly and accurately. This would not be practiable by manual methods.

2.2.7 Selection of Fuel:

Selection of fuel has to be done for those power plants which burn more than one type of fuel. This will mean calculation of total cost and would involve in addition the cost for fuel changover. Further, scheduling of fuel purchases and storage have to be calculated to minimise the total fuel cost.

These calculations involve complex system data evaluation and can be carried out very quickly by using computer.

2.2.8 Reservoir Management :

Reservoir management is the scheduling of Hydro-resources utilisation over a specified period of time in such a manner as to reduce the over all system generation cost. This optimisation must consider the following:

- water availability
- reservoir constraints
- system constraints
- down-stream constraints
- reservoir coordination
- river simulation and
- unit efficiency.

2.2.9 Hydro Thermal Generation Coordination:

As the name indicates, means evaluation of various generating conditions for optimum system operation. This is of primary importance to systems having both thermal and hydro-generation. The evaluation enables the load despatcher to minimise thermal generation, fuel costs, minimise the cost of purchased power and to a certain extent obtain maximum hydro-generation from the available water by proper programming.

2.3 Operation Control:

2.3.1 The operational control comprises problems that would be forced by the load despatcher during moment to moment control of system. The following functions come under purview of the operational control.

1. Load frequency control
2. Security monitoring
3. Supervision of switching stations, remote sub-stations and generating stations.
4. Economic depatch of MW and MVAr.

2.3.2 Load-Frequency Control:

Load frequency control is the regulatory function of simultaneously and automatically maintaining the frequency and tie line power transfer of a particular area according to a predetermined schedule. This is accomplished by measuring system frequency and tie line power deviations and modifying system generation in such a fashion as to reduce the deviations. Other functions such as inadvertent interchange balancing, integrated time error, incremental economic loading etc. can be incorporated in the load frequency function. The various methods of load frequency control and their application etc. are dealt in subsequent chapters.

2.3.3. Security Monitoring:

Security monitoring is the monitoring of the system status (generation, line flows, voltages etc.) to ensure that the continuity of service is maintained and that equipment limits are not exceeded. A simple security monitoring scheme would compare the status of the system equipment, steady state stability and protection limits. If any of these limits are approached, changes would be made to the system configuration to make it operate within these limits.

More involved schemes would encompass the above schemes plus a contingency evaluation. This contingency evaluation requires pre-study of the security of the system for various possible contingencies such as faults, loss of generation, loss of transmission etc. Modifications to the system configuration would be suggested if any potential contingency caused the system to operate outside the security limits.

2.3.4 Supervision of switching stations, remote sub-stations and remote generating stations.

This is the responsibility of all operations in switching stations, sub-stations and remote controlled generating stations. This requires knowledge of

- equipment status and availability.
- system values (Mws., Volts etc.)
- operating procedures.

2.3.5 Economic despatch of Mw and MvAr

Economic despatching is the function of specifying and maintaining the output of each station source and system voltage levels such that minimum system production cost is incurred. The out put schedule of each source includes both Mw and MvAr. Economic despatch includes consideration of system security constraints, hydro-thermal optimisation, generation incremental costs, unit commitment and system losses. Economic operation of power systems has been dealt in detail in subsequent chapters.

2.4 Operational Accounting and Review

2.4.1 Data Collection : is the process of gathering information to establish operating objectives and to assess and appraise over all system performance. The three types of data are

1. Periodic data
2. Demand data and
3. Event data.

Periodic data is obtained on a regular basis, for example hourly, daily and weekly etc. It is required for planning functions such as load forecasting, reserve evaluation etc.

Demand data is stored upon initiation at any time for use in planning and system performance assessment.

Event data is related to actual operations (i.e. breaker positions etc.) and is required for preparing such reports as customer outages, reports, equipment outage reports, fault analysis reports etc.

2.4.2 Assessment of system performance and planning:

This assessment includes such items as
- evaluation of system economic performance.
- appraisal of the operating plan from an economic and security point of view.

- equipment outage assessment.
- system reliability and security studies.
- fault studies.
- Load forecasting.
- long range planning and review including the assessment of generation, transmission and distribution facilities and power flow studies.

2.4.3 Interchange Billing: is concerned with the collection of interchange energy and demand data, the performance of arithmatic and logical operations on the data, in accordance with the interchange contracts and agreements and the preparation of statements or invoices. This process is normally carried out monthly.

2.5 The methods adopted for load fore-casting and scheduling of units, regulation of frequency and economic operation of Southern regional systems are discussed in Chapter 8. Regulation of tie line loads and system frequency plays an important part in operation of interconnected systems.[7] The techniques adopted for control load and frequency in power systems are dealt in the next Chapter.

CHAPTER - 3

LOAD AND FREQUENCY CONTROL

3.1 The necessity of maintaining frequency standards in power systems are as follows.

1) Most types of alternating current motors run at speeds that one directly related to frequency. Industries like paper mills, wire drawing machines etc. require constant fequency, other wise there products will be adversely affected.

2) The wide spread use of electric clocks has led to the need for close regulation of power system frequency. These clocks are expected to be correct within a few seconds at all times.

3) The operation of power systems will be smoother, efficient and better controlled if frequency error is kept within limits.

4) Maintenance of frequency and load in time lines of interconnected power systems is of paramount importance for satisfactory operations.

3.2 Mechanism of frequency control.

The frequency of a system is closely related to the power balance in the system. The generation can be controlled by controlling the prime movers torque. Since the generators are locked into synchronism with the system, the operating of the steam valves or water gates results in the advancement of the rotor angle by a few degrees. Due to this, there is an increase in delivered current and power. The resultant . . decelerating torque counter-acts the accelerating torque due to the valve opening. Hence with in each generator we have a delicate and automatic torque balancing mechanism. If all generators have a perfect torque balance, their speed and thus frequency will remain constant.

In practice such a balance is not possible owing to the random nature of the load demands. Hence instant by instant match between generation and demand is impossible. There will be a small surplus or deficiency in the generation and this ever present mismatch will cause frequency fluctuations.

Thus the variations in frequency exist, but should be controlled, so we should use the frequency variations in the sensor portion of the control system whose job is to provide automatic balance with minimum time lag.

3.3 Megawatt Frequency Control problem.

The real power in a system is being controlled by controlling the driving torques of the turbines. The governor plays an important part in power systems which controls the driving torque of the turbine generator thereby frequency of the system by constantly matching generation with the system load.

3.4 Speed Governing System

Fig. 3.1 shows the Schematic diagram of a speed governing system.

The speed governing system includes the speed governor, the speed control mechanism and the governor controlled valves.

The speed governor includes only those elements which are directly responsive to speed and which position or influence the action of other elements of the governing system.

The speed control mechanism includes all equipment such as relays, servomotors, pressure or power amplifiers levers and linkages between governor and the valves.

The governor controlled valves include those valves that controlled the energy input to the turbine and that are normally actuated by the speed governor through the medium of the speed control mechanism.

The speed changer is a device by means of which the speed governing system may be adjusted to change the speed or power output of the turbine in operation.

The per unit steady state speed regulation for a given speed changer position is given by

$$\text{per unit steady state regulation} = \frac{N_o - N}{N_R}$$

where N_o = Speed at No load.

N = speed at rated output

N_R = rated speed.

A straight line approximation of a speed Vs power output characteristic is shown in Fig.3.2. Steady state speed regulation shall be capable of adjustment values between 2.5 to 7 per cent[3] with speed changer set to give rated speed with rated power output.

3.5 Speed Droop Governing:

Speed droop is the automatic proportional reduction of governor speed setting as the turbine gate opening increases. This action produces a stability effect and is accomplished by a mechanical linkage from turbine servomotor directly to the governor through restoring mechanism. Under speed droop operation the turbine gates take up a finite position for a given speed deviation as determined by the degree of the droop setting. permanent speed droop is required for steady state stabilization. As the speed droop approaches zero, governor becomes isochronous. The load change tends to be infinite for any frequency change and demonstrates the need for a temporary speed droop factor which gradually diminishes to zero as the frequency change likewise approaches zero. with zero speed droop the steady state error will be zero. But the transient stability of the governor is deteriorated. The units tend to oscillate or hunt for any slight difference in frequency.

Speed droop is required for satisfactory parallel operation of generating units and for achieving stability. The generating unit with lower speed droop will cater proportionately more than the machine with higher speed droop.

$$\text{Speed Droop} = \frac{N_1 - N_2}{N_R} \times 100$$

where N_1 = Speed at zero gate opening.

N_2 = Speed at full gate opening

N_R = Rated speed.

Speed droop will be generally 1 to 5 per cent for Hydro plants[4] and 4 to 8 per cent for thermal units.

3.6 Performance equations and block diagram representation of a single area:-

A block diagram representing the several performance characteristics of a governor with illustrative transfer functions is shown in fig. 3.3. The block diagram is useful in understanding the location where relevant parameters are introduced and how further summation or multiplication etc. are to be made to derive at the final results.

The input to the speed governing system are the speed signals and the speed changer position. These signals call for changes in the governor controlled gates or valve positions which will change the input to the turbine. The change in steam or water flow or input to the turbine causes a change in the turbine torque which in conjunction with the load torque and the characteristic of the power system determines the change in the system speed.

The analysis which follows pertains for the most part to the response of the system for small changes.[1]

By writing the equation summing up the torques acting upon the inertia of power system we obtain-

$$Mp\delta + Dp\delta = \Delta P - \Delta L \qquad \ldots \quad (1)$$

where M = effective rotary iner- tia of area

p = differential operator d/dt (t = time)

δ = deviation of rotary m inertia from initial electrical angular position.

D = damping torque coefficient (that is the inherent net change of load and prime mover torque with frequency).

ΔP = component of change in prime mover torque produced by governor. Controlled valve motion.

ΔL = load change in area (aside from inherent change with frequency.

$p\delta$ = deviation from normal frequency or speed.

All quantities are in per unit values excepting time and angles which are in radians

Solving equation (1) for p we get

$$p\delta = \frac{1}{Mp + D} (\Delta P - \Delta L) \qquad \ldots . \quad (2)$$

The above relation is shown in the block diagram vide fig. 3.3.

The quantity M is directly related H constant used in stability studies. The following relationships a re well known

$M = 4\pi fH$ where f = frequency in cycles/Sec.

and $H = \dfrac{0.231 \times WR^2 \times rpm \times 10^{-6}}{KVA\ (Base)}$

Damping torque coefficient D is given by

$$D = \frac{\delta\,(\text{load torque})}{\delta p \delta} - \frac{-\delta\,(\text{turbine torque})}{\delta p \delta}$$

The quantity $\dfrac{\delta\,(\text{turbine torque})}{\delta p \delta}$ is the change in the turbine torque with, constant valve position may be taken as approximately equal but opposite in sign to the steady state prime mover torque. The induction and synchronous motors with their mechanical shaft loads develop the $\dfrac{\delta\,(\text{load torque})}{\delta p \delta}$ component of the damping torque coefficient.

The dynamic response of non heat turbines may be approximated by a single time lag, (T_s) shown in fig. 3.3 of approximately 80 radians or 1/4 second.

Then $$\Delta P = \frac{1}{T_s p + 1} \Delta P_V \qquad \ldots\ldots (3)$$

Where ΔP_V = change in valve position.

In the case of reheat turbines the transfer function is given by

$$\Delta p = \left(\frac{CT_R p + 1}{T_R p + 1}\right)\left(\frac{1}{T_s p + 1}\right) \Delta P_V \quad \ldots (4)$$

Where T_R = time lag association with reheater.

C = proportion of torque developed in high pressure element.

Typical values of C are 1/4 to 1/2 for T_R 3 to 5 seconds.

The speed response is given by

$$\Delta P_V = \frac{-1}{TGp + 1}\left(\frac{1}{R}\, p\,\delta + \Delta P'\right) \quad \ldots \quad (5)$$

where TG = Governor time lag (100 radians)

R = speed regulation.

$\Delta P'$ = change in speed changer position.

For Hydro turbines the large inertia of water used as a source of energy causes a considerably greater time lag in the response of prime mover torque to change in gate position compared to the response of steam turbines. Also for hydro turbines there is an initial tendency for the torque to change in direction opposite to that finally produced. The transfer function for hydro turbine is presented by

$$\Delta P = \frac{-T_w p + 1}{(T_w/2)\, p + 1}\,\Delta P_V \quad \ldots\ldots \quad (6)$$

where T_w = nominal starting of water in penstocks in seconds = $\frac{\lambda L}{gH}$

L = Length of pipe in ft.

λ = water velocity in ft./second

H = pressure head in ft.

g = acceleration of gravity in feet per sec^2.

The value T_v may vary from 1/2 to 4 seconds. In case of hydro turbines ΔP_v is the change in gate position.

The hydro turbine speed governor responce is approximated by the relation

$$\Delta P_v = -\left(\frac{1}{T_G p + 1}\right)\left(\frac{T_R\, p + 1}{(r/R)\, T_R p + 1}\right)(1/R)p\,\delta + \Delta P' \quad \ldots (7)$$

with the following approximate values for the parameters

R = Steady state speed regulation
= 0.05 to 0.167

r = transient speed regulation
= 0.3 to 1.2

T_R = time constant associated with the temporary droop compensation = 0.5 to 0.64 seconds.

T_G = Governor constant = 0.6 second.

The block diagram for an isolated hydro generation is shown in the fig. 3.3

Referring to the term $\frac{1}{R}\left(\frac{T_R p + 1}{(r/R)\, T_R p + 1}\right)$ in equation 7, for a step change p becomes infinity and the term becomes

$$\frac{1}{R}\left(\frac{T_R\, p + 1}{(r/R\, T_R p + 1}\right) = \frac{1}{r} \quad \ldots\ldots (8)$$

Initially because of two temporary droop compensation, the regulation appears to be r .

In steady state when p = 0 we obtain

$$\frac{1}{R} \left(\frac{TR\,p + 1}{(r/R\ TRp + 1} \right) = \frac{1}{R} \quad \ldots \quad (9)$$

Thus R is the regulation in the Steady State.

3.7 Inter-connected Systems.

In isolated or independent systems the regulation can be achieved by continuously controlling one variable, viz. frequency. In an inter-connected system, several utilities or areas are connected by tie lines. The schedule of exchange of power between areas assume great importance. For satisfactory operation of the inter-connected systems the two variables namely load and frequency have to be regulated. The deviation in frequency and tie line power will be responsible to emit regulating control signals from the controllers making the connections in right direction. Additional variable could be the time error and indvertant interchange error factors etc. Once the tie line schedules are met with or the net s interchange of each area is maintained as per schedule, the frequency is automatically maintained.

Bascially there are three types system controls and these are generally adopted for regulation of load and frequency of tie lines in an inter-connected systems.

i) Flat frequency control.

ii) Flat tie line control.

iii) Tie line load bias control.

3.8 Flat Frequency Control:

In large inter connected systems the centrally located station will be assigned with the regulating duty. The regulating duty is entrusted with one machine for smaller systems or a group of machines in a large network system and the centrally located station has to regulate the load changes in all tie lines and the areas. The plants in the other systems will be operating at base loads. Such an arrangement may be workable for the inter-connection of the few areas provided;

1) The tie lines are strong enough to take all variations in the power flow ensuring sufficient transmission capacity.

2) The regulating capacity of the frequency controlling plant is sufficient for the regulation of the variations of entire system.

3) There are no contractual obligations between operating areas.

Hydro units, due to their performance characteristic will have longer band for regulation, say 50% to 100% of load. Thermal units normally working at base load units will have a limited regulating band of 5 to 10% of the maximum capacity. (Maximum may be order of 20 to 30 per cent of the capacity). Larger the regulating capacity in a system, the larger the regulating band and finer will be the regulation with close tolerances. In 1966 the total regulating capacity in France was

10,000 MW representing 60% the total on line capacity. The regulating band provided by such sets was as high as ± 1800 MW[2].

3.9 Flat Tie Line Load Control.

In flat tie line control, the larger area is entrusted with the task of maintaining system frequency and the smaller systems will maintain their tie line power changes in accordance with preset schedule. Referring to fig. 3.4 frequency controlling units are in system A and the tie line regulating units are in system B.

The frequency of the system and the power exchanges between systems is maintained constant during the steady state. Any change in the steady state load of system A is ultimately observed by the master frequency regulating units GA in A, while any change in the steady state load of system B is ultimately absorbed by tie line regulating unit GB.

The flat tie line load control can be adopted when a larger system is inter-connected with the smaller system. France is inter-connected with Belgium, Sweden with Denmark, NWEB with SSEB on flat tie line control basis[5]. Larger power system, viz France, Sweden are regulating the frequency. The smaller systems like Belgium and Denmark are controlling the tie line power. The systems are adhering to the contractual obligations and there will be no fear of over loading the transmission lines.

3.10 Tie Line load bias Control.

Flat tie line load control and selective frequency concepts have been further improved upon to achieve faster restoration of normalcy. To meet these objectives all systems in the inter connection participate in bringing the system frequency back to the standard value in the event of frequency deviation due to an outage of one area of the system.

The principle adopted in the most appropriate solution to the problem is that each area will maintain the interchange schedule meticulously when the frequency is normal. When there is a deviation in frequency, the tie line schedules are temporarily altered in an attempt to help each area which require assistance. Once the frequency is restored, the additional assistance is withdrawn. Each area under tie line load bias control will have a tie line schedule biased by the frequency i.e. net interchange is increased in the event of the frequency is below the normal and vice versa . Once the normalcy is achieved, the tie line loadings will be back to the original schedule.

Thus there will be temporary relaxation in the interchange schedules with respect of assisting the affected areas. Each area will ultimately take over the load changes emanated from it. This type of control is very popular and almost universally recommended.

The bias setting [illegible] (in MW per cycle per second) primarily represents the change in power generation for a change in system frequency by one cycle per second. If dp be the sum of departures from the scheduled power flow on various lines consequent to change of frequency df, the regulating parameter for the system then becomes dp + Kdf.

The tie line load bias control can operate over a wide range varying from flat frequency control to flat tie line control depending upon the amount of frequency bias (K) used in the control constant dp + Kdf, as shown in fig. 3.5. If the frequency bias K is zero then the control is purely of flat tie line type where as if the bias is considerably high so that the power portion dp is negligible with respect to Kdf, then the control is purely flat frequency type (shown in fig. 3.5).

Thus the tie line bias control is very useful for coordinated operation of power systems as it provides convenient means for differentiating responsibility for the system load changes.

3.11 Load Phase Control.

The application of tie line load bias control is basically the control of dp + Kdf for a stabilised system. This control constant could be applied on a system in several ways viz. integrating dp only, df only or suitable combination of dp and df so that the control signal thus derived gives damped control to achieve zero steady error.

In load phase regulation in respect of single area only the frequency portion is integrated. In load phase energy regulation in respect of inter connected systems both variations in the frequency (df) and the power (dP) are integrated.

Load phase control concept make use of the fact that there will be a phase angle difference between system voltage and voltage of a standard frequency source whenever there is a deviation in frequency. It is equal to the integral of the difference between system and standard frequency.[1] They will have to be matched with the values of the integral of the frequency difference. Here the regulating quantity is the frequency. The application of this method leads to the subjecting the out puts (Load) of regulating machines to the value of phase difference (integral of frequency deviation).[1] Hence this is known as load phase control.

3.12 Level Control:

Electricite de France have developed this technique based on load phase energy control. The frequency and tie line power deviations are integrated in the form of phase deviation $d\psi = \int_0^t \left(\frac{dp}{k} + df\right) dt$. If $\pm$ R is the regulating band of a regulating machine the ratio $\frac{\alpha\, d\psi}{|R|}$ is called the "level" denoted by N and α is a constant representing the regulating power of the machine expressed in MW per radian. The value of N varies from + 1 to - 1.[1] This is determined at the National despatching station at Paris and transmitted to each regulating machine via the respective regional stations.

Here load variation on each group of regulating stations is controlled at constant intervals by impulses of constant amplitude, but the duration is proportional to the control error. These impluses act on the governor speeder motor.

$$\text{Level } N = \frac{\alpha \, d\psi}{|R|} = -\frac{dp}{R}$$

$$= \frac{\text{variation of power to be obtained from regulating station.}}{\text{Half regulating band of the regulating station}}$$

The level is a number which can be used to inform each regulating station at any instant of the regulating output required as a proportion of the regulating band.

3.12 Bias Setting:

The extent of area net inter change schedule shift with frequency is determined by the slope of the bias regulating characteristic. The reciprocal of the slope is defined as bias. It is usually expressed in megawatts per one-tenth ecycle[6].

3.13 Area Requirement:

Area requirement is a measure in magawatts of the prevailing area generation error. It is the amount by which area is off its biased net interchange schedule. It is the amount by which the area generation must be changed by supplementary area regulation in order that the area correct its net interchange and do its share of system frequency regulation.

The area requirement error ACE (referring to fig.3.5) may be written as

$$ACE = C = T_1 - T_1'$$
$$= (T_0 - T_1') - 10\,B\,(F - F_1)$$
$$= \triangle T - 10\,B\,(\triangle F)$$

where $\triangle T$ is the difference between the 50 cycle interchange schedule To and the prevailing net interchange T_1'.

B is the bias setting in megawatt per one-tenth cycle

$\triangle F$ is the difference between normal frequency F_0 and the prevailing frequency F_1.

3.14 Regulation:

3.14.1 In isolated systems or independent systems regulation can be effected manually by varying one variable namely 'frequency'. In an inter-connected systems it will be difficult to maintain system frequency and tie line loadings manually since continuous control operation is needed. To achieve satisfactory operation of the system it would be necessary for an operator to observe system frequency and tie line loadings steadily and make continuous adjustments of the position of the governor motors of various generator units. Automatic control could be adopted for maintaining the desired operating conditions more satisfactorily.

Frequency bias tie line control is adopted manually in England and automatically in some continental systems.

The duties of frequency control and tie line loading can be assigned to the few regulating stations and the generation of power at remaining stations on the system can be manually despatched. Automatic regulation becomes necessary particularly when the power exchanges with the neighbouring systems have to be maintained at agreed values with limited fluctuations.[1] Manual regulation of frequency gives an accuracy which is sufficient so far stability of frequency is concerned.

Manual regulation of generation is also found to satisfactory in PJM system (Pennsylvania- New Jersy-Maryland) where 12 electric power systems are inter-connected on a single system basis. The combined estimated installed capacity in 1966 was over 19000 MW operating in more than 60 major generating stations and the peak load was 17850 MW.[2] The PJM system have provided high capacity inter system ties to permit free flow of power among the utilities. It was only in 1962 when the system was connected with 2 or 3 neighbouring inter connected systems, that it become necessary to take recourse to provide automatic equipment to regulate the flows on the tie lines with neighbouring inter-connections.

3.14.2 Centralised Automatic Regulation:

The centralised automatic regulation which is more commonly used at present in having automatic frequency regulator installed at a central point of the system which controls permanently by remote control the power out puts of the machines in the regulating stations. Its role is not only to bring about a total variation in case of frequency deviation of the generating capacity, but also to distribute under predetermined conditions, this variation among all the regulating machines.

Extensive telemetering and tele-control channels are required for transmitting the command signals. Central control is entirely responsible for the frequency regulation.

3.15 Equipments for automatic load and frequency control.

3.15.1 Master Load Frequency Controller:

When the frequency varies from the controlled setting the controller galvanometer, a detector of current unbalance deflects in the direction depending upon the unbalance current flow through the bridge. The direction of current depends upon whether the frequency is high or low. The controller mechanism detects the galvanometer deflection and closes the contacts to operate the governor motor. These controller contacts connect in parallel with contacts on the governor switch (in manual operation the operator closes the contact to send an impulse to the same motor). When the frequency is high, deflection of galvanometer sends an impulse to run the governor motor in closing direction, when low the impulse sent enable the motor to rotate in opposite direction. The frequency controller is sensitive to variations of frequency of 0.005 cycle[7] and starts correction before the deviation in frequency is appreciable.

The methods adopted to send the impulses to the governor motor are:

1) by varying the number of impulses in a given time and

2) by varying the duration of an impulse.' The second method appears to be satisfactory. In case of proportional step controller, the cam and contact mechanism is designed making this correction possible. Duration of impulse sent to the governor motor is directly proportional to the deviation of the frequency from the control setting. The greater the deviation from the control setting, the greater would be the correcting impulse. As the frequency approaches the control point the correcting impulse decreases correspondingly thus accomplishing restoration of frequency more rapidly than an impulse of constant duration and 2) prevention of over travel or hunting. The various types of controls are obtained by manipulating the selector switches.

3.15.2 Automatic Time Error Correction.

If the service requires close adjustment of integrated frequency or time, automatic time error correction can be provided. The time shown by a synchronous clock is compared with a master clock. The control point of the frequency controller is automatically adjusted to return any accumulated system time error to zero. Dynamic type tuning forks, crystal- controlled oscillators are generally used for reference time standard.

A station can be placed on flat frequency control with automatic time error correction by operation of selector switch position. This switches the galvanometer from the manually adjustable control dial to one automatically adjusted by the time error equipment (fig. 3.6).

Modern time frequency standard is a standard clock powered by the output of a crystal oscillator whose frequency is successfully divided to a usable value. This instrument keeps time to within one second per day.

3.15.3 Automatic Unit Load Distribution:

If the load variation is too large, it is desirable that several units participate in this regulation to limit the load swings on each unit. If the over all efficiency characteristic from no load to full load of the units are same, this load may be distributed in proportion to their capacities. This arrangement is called proportionate load distribution. For units with wide differences in efficiency it is better economy to divide the load according to the efficiency characteristic. This arrangement is called ecnomic load distribution.

3.15.4 Proportionate Load Distribution:

with proportion load distribution each unit has a thermal converter to measure the unit output, a unit load controller operating on its governor regulating motor and a unit selector switch to give the desired type of control on that unit. Any unit say unit No.1 is placed on flat frequency control by simply switching the master frequency load controller impulses to its governor motor making that unit responsive to slight variations in frequency. The correction of units one and two on flat and proportional load control respectively are shown in fig. 3.7. The thermal converter of each unit produces a low voltage D.C. potential proportional to watts. This potential form unit 1 regulating the frequency is opposed through the galvanometer of unit 2 to the potential of a similar thermal convertor of unit No.2.under normal conditions these potentials will be equal and the galvanometer on unit 2 will indicate a balance.

Referring to fig. 3.7 the master load frequency controller is operating on unit one and varying the unit load to maintain system frequency. As the load on unit one increases and becomes greater than the load on unit 2 the potential produced by the thermal convertor will be greator and the galvanometer on unit 2 indicates this unbalance. This causes the mechanism in controller 2 to route corresponding impulses to increase the load on that unit untill the potential produced by its thermal convertor exactly equal to that produced by the thermal convertor on unit one. Even a slight unbalance in loading between the two units causes the 2nd unit to readjust its load untill it equal that of the master unit. The convertors are designed so that the D.C.

potential is proportionate to actual kilo-watts and independent of variations in power factor.'

When the units are placed under control the potentials of their thermal converter are opposed through their galvanometers to the potential on the master unit convertor as shown for unit two. As unit one is controlling frequency, picks up or drops off load, the convertors on the remaining units cause them to pick up on drop off in the same manner, so that the load swings will be divided among all units in the station. Any number of units may be connected in parallel with their convertor potentials opposed to the converter potential of the unit operating as master and all the units participate equally in regulation. By this arrangement the load distribution is automatically maintained with no tendency for an unbalance of the load among units in the station regardless of difference in their individual governor characteristics.

3.15.5 Economic Load Distribution.

With economic load distribution as with proportionate distribution each unit has a load controller operating on its governor motor and again any unit in the station may act as a master by switching the impulses from the master load frequency controller to the governor motor. However the load of the remaining units is maintained in such a ratio that any given station load is divided not necessary proportionately among units, but economically for maximum over all station efficiency. This is done by the following manner.

The thermal converter of each generator operates a standard graphic wattmeter. This watt meter besides giving a graphic record of the unit load drives a slide wire or transmitter. The potential on this slide wire takes the place of the D.C. potential of the thermal converters, used for the proportionate load distribution. The slide wire is designed so that its potential is proportional to the slope of the input-out put curve for the its unit. When potential of two or more transmitters are opposed through the galvanometers of their respective controllers. The controllers operate to route the impulses to change the load until the respective transmitter potentials are equal to that of the potential on the master unit. This is similar to operation for proportionate load distribution but because of tapesed slide wires, the balance points will be reached when the load distribution between units is in proper ratio for minimum over all efficiency, not necessarily an equal load on each unit.

When more than two units are connected in this manner, the operation is extremely similar. As the station load varies with loads on the individual units vary, but the controller operate on their units always to maintain economic load distribution.

3.16 Proportional and Integral Controller

Karnataka and Andhra Pradesh in the Southern region have already procured Brown Boven make type DHRB load frequency equipment whose control function is based on the sum of proportional and integral portions. Southern Regional Electricity Board is also planning to procure similar equipment for control of the region. The benefits achieved to the region by adopting different frequency controls, is discussed in Chapter 8.

Further we have seen that the regulating stations will maintain frequency for variations in tie line loading For optimum economy such variations of load should be shared by different regulating units such that incremental cost of production should be same from each source at all points in the network. The economical aspects of loading of units, for optimum economy and different techniques followed to achieve our objectives are discussed in the next chapter.

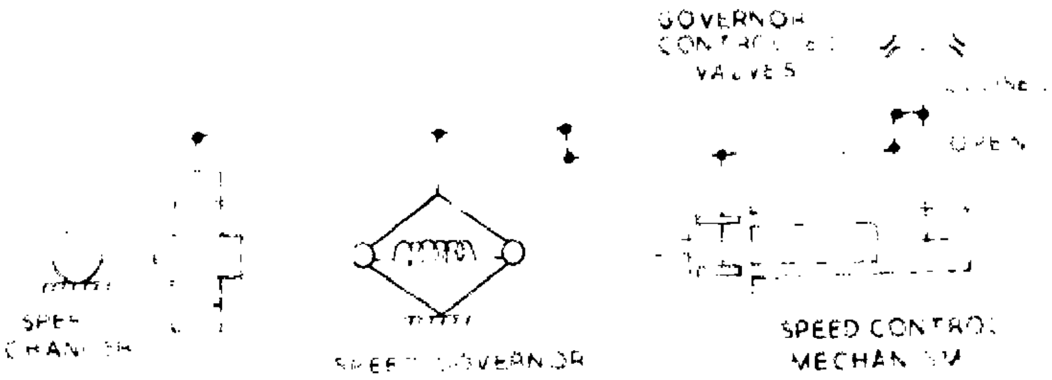


FIG. 3.1 _ SCHEMATIC REPRESENTATION OF SPEED GOVERNING SYSTEM

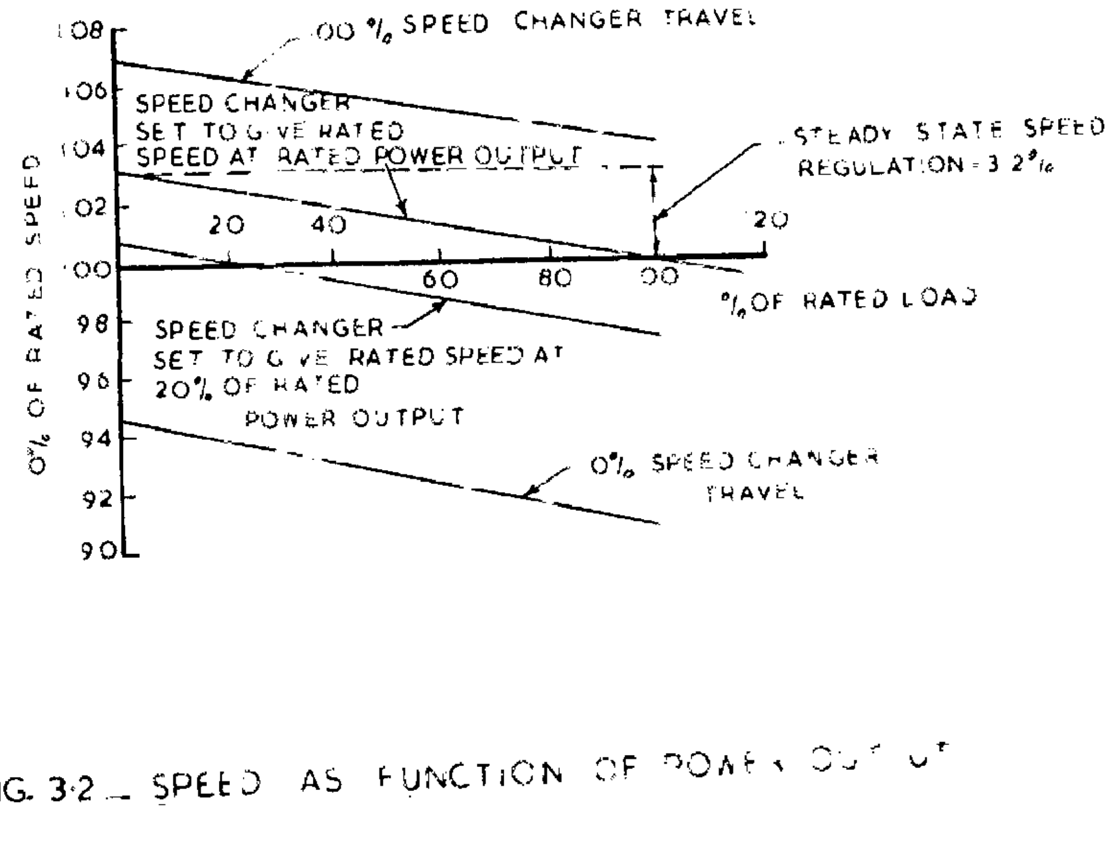


FIG. 3.2 _ SPEED AS FUNCTION OF POWER OUTPUT

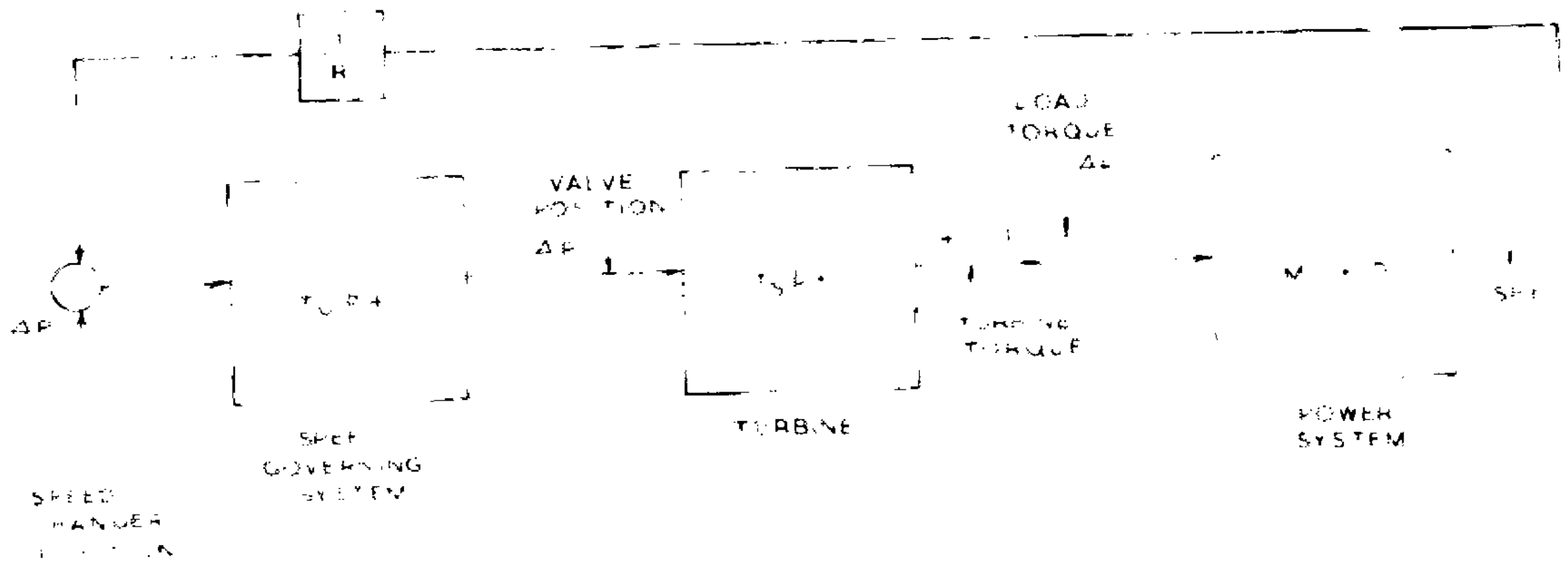


FIG. 33 _ BLOCK DIAGRAM REPRESENTATION OF ISOLATED AREA WITH ILLUSTRATIVE TRANSFER FUNCTIONS

For hydro turbine and governor ... transfer functions ... diagram are: ... Speed governing system ... 2 Turbine

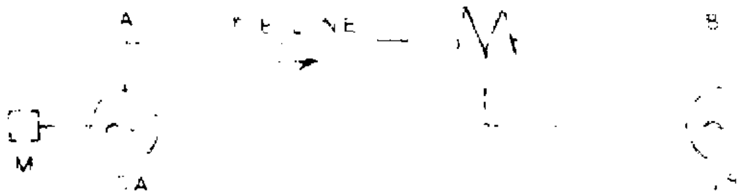


FIG 3.4 FLAT TIE LINE CONTROL

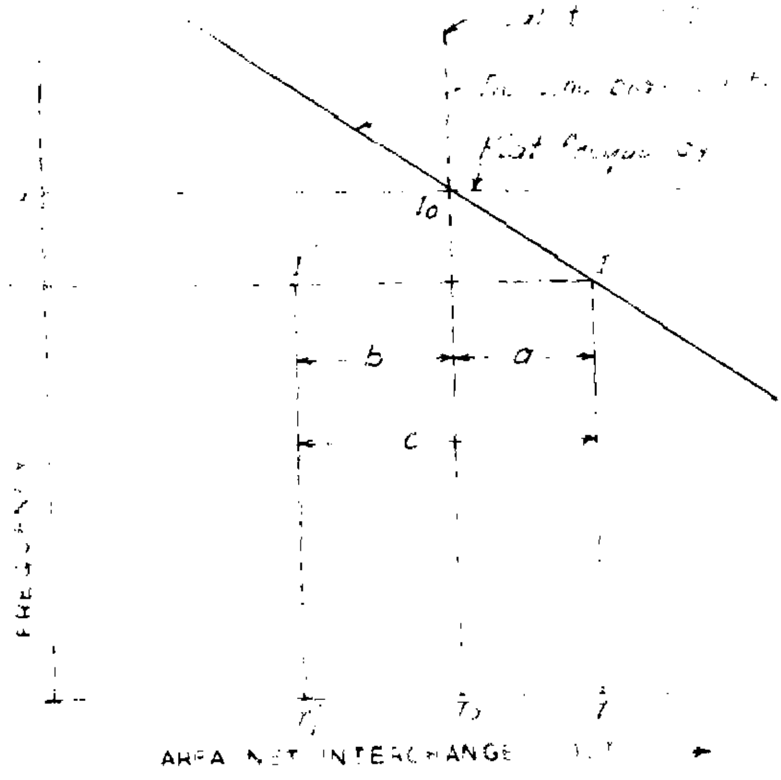


FIG 3.5 TIE LINE BIAS REGULATING CHARACTERISTIC

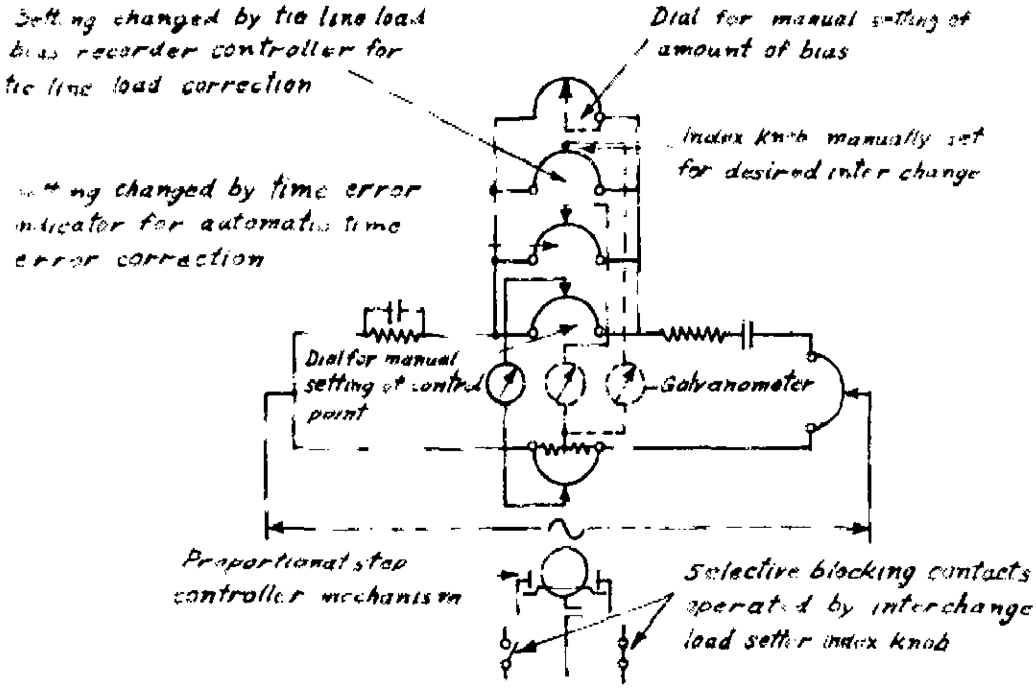


FIG. 3·6 WIRING DIAGRAM OF MASTER CONTROLLER.

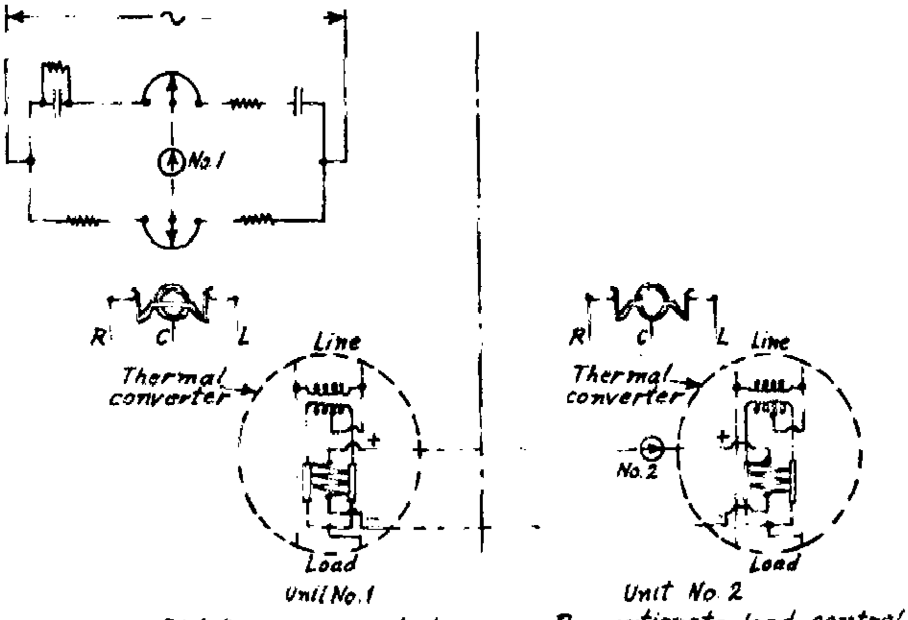


FIG. 3·7 SCHEMATIC DIAGRAM OF CONTROLLERS CONNECTED FOR PROPORTIONATE-LOAD DISTRIBUTION IN MULTIUNIT GENERATING STATION.

CHAPTER - 4

ECONOMIC LOAD DESPATCHING

4.1 With power systems doubling every 5 years in undeveloped countries and doubling every 10 years in developed countries, fuel costs raising rapidly and unit sizes increasing even more rapidly, the importance of system operation for optimum economy has increased tremendously. While the primary responsibility of the power system despatcher is to have power availablw whenever and whereever the system demands it, and he must also furnish this power at the lowest possible cost.

4.2 Economic Operation:

The job of operating power system for optimum economy has two important factors, first what machines should be operated and when should they be put on line for a given load and the second with given machines on line how should they be loaded.

The determination of which machines should be operated and when, involves not only the "fixed cost" portion of the operating expense, (the start up cost and the no load input to the machine), but also the spinning reserve and other system requirements. In addition to the fixed cost portion, the cost of operating a machine on various loads (or the variable cost of operation) and the effect of transmission losses also influence this determination.

In general in a given station the units are placed in service in ascending order of their heat rates assuming the cost per BTu to be the same.[1] To determine the most economic combination of units for a given station load it is necessary to plot the total station heat rate curves of successive combinations and to note the combination providing the lowest heat rate for a given station load.[7]

Another problem of importance is to determine the economic advisability of taking units off the line for relatively short periods of time such as between the morning and evening peaks. This determination is based upon the calculating the total cost fuel input in Rs. to the system during this period of time when the units in question both on and off the line. This calculation should include cost of restoring units under consideration back in service and losses involved in banking the boilers.

Once the decision has been made as to what machine will be on line, there remains the task of determining machine loading for various system loads. This is a variable cost portion of operation. Neglecting losses, we obtain optimum economy when all machines are loaded such that the "incremental costs of generated power are equal at every point on the power system.

The incremental cost characteristic for a machine is obtained from its input output characteristic as shown in fig. 4.1. The slope Y/X of the input-output curve is plotted against output to obtain an incremental heat rate curve. The incremental heat rate curve is in BTUs/Mwhr, and by multiplying this by the fuel cost in Rs/BTh, we have the incremental cost curve in Rs./Mwhr. The mathematical equation for optimal scheduling of generation is given by

$$\frac{d F_n}{d P_n} = \lambda \qquad \ldots (1)$$

where $\frac{dF_n}{dP_n}$ = incremental cost of production of unit n in Rs/Mwhr.

= incremental cost of received power in Rs/Mwhr.

F_n = input to unit n in Rs per hour.

P_n = output of unit n in megawatts.

4.3 Scheduling of generation neglecting losses:

The first step in scheduling is that of predicting the daily system loads Vs time. The total system generation necessary to supply this load includes the spinning reserve requirements and the tie line flows. It is determined that certain machines are to be operated and a loading schedule is to be based on loading the machines at equal incremental costs.

To schedule generation at equal incremental costs a number of machine characteristics properly adjusted for fuel costs are to be combined on a single plot as shown in fig. 4.2 for three machine operation. The inter section of horizontal line X-X gives each machine's out put for the particular incremental cost selected.

If the sum of the machines out puts $P_1 + P_2 + P_3$ is less than the desired system load we try a higher incremental cost such as the line X' -X' and repeat this process until the total outputs equal to the system load. This would be done for the entire daily load curve and the individual machine out puts determined for each system load level. If a fourth machine were to be added to the line the incremental cost level for any given system load would be lowered. Similarly if one of the three machine were taken out of line the incremental cost would have to raised to carry out the same system load with two machines.

Since both fuel cost and number of machines on the line affect the loading of all generators for any system load, an unpredicted change of either of these necessiates a completely new schedule for optimum economy.

The schedule of generation for operation at equal incremental costs may be efficiently done by the use of incremental cost slide rule. figure 4.3 illustrates an incremental cost slide rule for a three machine system. This slide rule consist of a essentially of a logarithmic calibration scale, a moval strip for each generator unit and a fuel cost adjustment scale. The calibration scale is graduated in BTU per Kwhr to a logarithmic scale. Each movable strip is calibrated in Mws and indicates the relation between the incremental fuel rate and out put of a given generator unit. Differences in fuel costs may be accounted for by displacing a given generator strip to a position on the fuel adjustment scale corresponding to the ratio of fuel costs. For a given incremental cost of received power corresponding generator out puts can be read directly from the strips.

4.4 A Despatching Computer Neglecting Losses.

Fig. 4.4 describes the essential elements of a computer which can do the loading slide rule work, that is, computes the machine out puts for generation schedules based on loading at equal incremental cost of generated power. The computer shown in the fig. 4.4 is for a system with two stations each with two machines. To use this computer for calculating machines and stations out puts we should set the system load and tie line schedules. The required generation for the system is automatically compared with the computed total generation and the comparing unit adjusts the outout level of the cost unit whenever the two are not equal. The incremental cost level is raised if the computed generation is less than that required and vice versa. The output of cost unit would be generally be a voltage which is raised or lowered for different cost levels. The output is fed to the four individual machine incremental cost units (or function generators). There is a function generator for each machine on the system and each one has the incremental cost characteristic for its associated machine set into it. These function generators corresponds to the machine slides on the slide rule. For any given input incremental cost of the function generator develops a signal proportional to the proper machine output for the input cost level.' The functional generator then provides the same information we would obtain manually from the incremental cost curves or incremental slide rule.

The above type of computer nearly replaces the loading slide rule' would not be economical in most cases since it automates the task of which is easily performed manually.'

4.5 Other methods of scheduling Turbine Generator.

Although the criterion of equal incremental production cost will result in optimum economic scheduling of generation, the following methods of scheduling are some times still found useful.'

i) Base loading to capacity: The turbine generators are successfully loaded in order of their efficiences.

ii) Base loading to most efficient load.

The turbine generator units are successfully loaded in ascending order of their heat rates, to their most efficient loads when all units operating to capa city in the same order.

iii) Proportional to capacity: The loads on the units are scheduled in proportion to their rated capacity.

4.6 Transmission Losses

With the development of integrated power systems and the inter-connection of utilities for the purpose of economy interchange, it is necessary to consider not only incremental fuel costs but also incremental transmission losses for optimum economy. Another important problem in operation of interconnected systems is the determination of transmission losses for the purpose of billing and also wheeling power in various interconnected transactions.

The potential savings to be achieved by attention of transmission losses in economy despatch depends on the size and nature of the power system. A closely knit metropolitan network may find that the potential savings are only modest. On the other hand a far-flung network covering large geographical areas may find potential savings from this source to be of considerable magnitude. One large power system which serves an area of about 100,000 sq. miles estimates that the fuel cost of power lost in transmission is approximately Rs. 375 Lakhs per year[7]. It has reported savings of approximately 4% that figure i.e. Rs. 15 Lakhs per year by the use of an economy despatch system that gives approximate consideration to transmission loss factors.

4.7 Transmission losses as a function of plant outputs

For expressing the transmission losses interms of plant out puts, let us consider a system as shown in fig. 4.5 consisting of two generators and one load. If R_a, R_b and R_c are the resistances of lines a, b, and c respectively, then the total 3 phase system loss is given by

$$P_L = 3\ |I_1|^2\ R_a + 3\ |I_2|^2\ R_b + 3\ |I_1 + I_2|^2 R_c \quad \ldots(2)$$

If we assume that I_1 and I_2 are in phase currents and P_1 and P_2 are the power out puts of plant 1 and 2 at power factors pf_1 and pf_2 respectively.

$$\text{Then}\quad |I_1| = \frac{P_1}{\sqrt{3}\ |V_1|\ (pf_1)} \quad \text{and} \quad I_2 = \frac{P_2}{\sqrt{3}\ |V_2|\ (pf_2)}$$

on substitution in equation (2) we get

$$P_L = P_1^2 \frac{R_a + R_c}{|V_1|^2\ (pf_1)^2} + 2\ P_1 P_2 \frac{R_c}{|V_1|\ |V_2|\ (pf_1)(pf_2)} + P_2^2\ \frac{R_b + R_c}{|V_2|^2\ (pf_2)^2} \quad \ldots(3)$$

$$= P_1^2\ B_{11} + 2P_1P_2\ B_{12} + P_2^2\ B_{22} \quad \ldots(4)$$

The terms B_{11}, B_{22} and B_{12} are called as loss formula coefficients or B coefficients.

$$\text{where}\quad B_{11} = \frac{R_a + R_c}{|V_1|^2\ (pf_1)^2}, \quad B_{12} = \frac{R_c}{|V_1|\ |V_2|\ (pf_1)(pf_2)},$$

$$B_{22} = \frac{R_b + R_c}{|V_2|^2\ (pf_2)^2}$$

Calculation of transmission loss coefficients are more complicated and time consuming for a system consisting number of sources and loads. A very popular method of calculating loss coefficients from Kron's method of applying tensor analysis to power systems to reduce the system to an equivalent one with a single hypothetical load. Fig.4.6 represents two generating plants connected a transmission network with an arbitrary number of loads. R_k is the resistance of branch K and N_{k1} and N_{k2} are current distribution factors. The transmission loss for such a system is given by

$$P_L = \sum_k 3 \; |I_k|^2 R_k \qquad \ldots(5)$$

$$= \frac{P_1^2}{|V_1|^2 \; (pf_1)^2} \sum_k N_{k1}^2 \; R_k + \frac{2 \; P_1 \; P_2 \cos(\sigma_1 - \sigma_2)}{|V_1| \; |V_2| \; (pf_1)(pf_2)} \sum_k N_{k1} N_{k2} R_k + \frac{P_2^2}{|V_2|^2 \; (pf_2)^2} \sum_k N_{k2}^2 \; R_k \qquad \ldots.(6)$$

where $\sum_k$ indicates summation to include all branches. The above equation reduces to

$$P_L = P_1^2 \, B_{11} + 2 \, P_1 P_2 \, B_{12} + P_2^2 \, B_{22} \qquad \ldots (7)$$

Where B_{11}, B_{12} and B_{22} are loss coefficients.

The general form of the loss equation for any number of sources is

$$P_L = \sum_m \sum_n P_m B_{mn} P_n \qquad \ldots(8)$$

where $\sum_m$ & $\sum_n$ indicate independent summation to include all sources.

A general expression for loss coefficient is

$$B_{mn} = \frac{\cos\ (\sigma_m - \sigma_n)}{|V_m|\ |V_n|\ (pf_m)\ (pf_n)} \sum_k N_{km}\ N_{kn}\ R_k$$

Equation (8) is based on the following assumptions.

1. All load currents maintain a constant ratio to the total current.

2. The generator bus voltage magnitudes remain constant.

3. The ratio of reactive power to real power of any source remains a fixed value.

4. The generator bus angles remain constant.

4.8 Augmented loss equation.

The traditional loss equation (8) is said to be limited in its practical applications since the assumptions on which it is based are sub-stantially invalid on typical power systems. It has been pointed that with the changes in the system load and reactive requirements, the equation becomes quite inaccurate.

An augmented or general total transmission loss equation has been developed (8) based on more realistic assumptions.

$$P_L = \sum_m \sum_n P_m B_{mn} P_n + \sum_n B_{n0} P_n + K_{L0} \quad \ldots (9)$$

where

B_{n0} is a constant related to source n

K_{LO} is a constant that may be regarded as representing total system losses under imaginary condition of Zero system power supply.

B_{mn} is not necessarily equal to B_{nm}.

4.9 Incremental Transmission losses.

Incremental transmission loss for a specific source is the change in transmission loss related to that source when the source output is changed by a small amount. It represents the fraction of the incremental power of that source which is lost in transmission. The partial derivative of equation (8) with respect to a given source represents the incremental transmission loss for that source in accordance with the following equation

$$\frac{\delta P_L}{\delta P_n} = \sum_{n} 2 B_{mn} P_m \qquad \ldots(10)$$

where $\frac{\delta P_L}{\delta P_n}$ is the incremental transmission loss for source n.

For a area having two sources, the incremental transmission loss of each source is given by

$$\frac{\delta P_L}{\delta P_1} = 2P_1 B_{11} + 2P_2 B_{12}$$

$$\frac{\delta P_L}{\delta P_2} = 2P_2 B_{22} + 2P_1 B_{21}$$

For more accurate results partial derivatives of of augmented equation are considered

$$\frac{\delta P_L}{\delta P_n} = \sum_{m} 2 \; B_{mn} P_m + B_{no} \qquad \dots (11)$$

for two source the incremental loss equation becomes

$$\frac{\delta P_L}{\delta P_1} = 2P_1 B_{11} + 2P_2 B_{12} + B_{10}$$

$$\frac{\delta P_L}{\delta P_2} = 2P_2 B_{22} + 2P_1 B_{21} + B_{20}$$

The preferred incremental loss equation (9) includes 3 types of B constants for source n as follows

B_{nn} self constants which are positive.

B_{mn} mutual constants which may be positive or negative.

B_{no} the added constant which may be positive or negative.

4.10 Distribution of load between plants considering transmission Losses:

Transmission loss as an additional constant has been considered in deriving the equation for incremental cost of power generated.

In the equations

$$F_t = F_1 + F_2 + \dots F_k = \sum_{n=1}^{k} F_n$$

$$P_t = P_1 + P_2 + \dots P_k = \sum_{n=1}^{k} P_n$$

where F_t is the total fuel cost and P_t is the total power inputs to network.

The constraining relation on the minimum value of F_t is

$$\sum_{n=1}^{k} P_n - P_L - P_R = 0$$

where P_L = total transmission loss, P_R is total power received by loads.

By method of Lagrangian multiplier we introduce the expression $\mathcal{F}$ such that

$$\mathcal{F} = F_t - \lambda \left(\sum_{n=1}^{k} P_n - P_L - P_R \right)$$

Minimum fuel cost F_t is obtained when $\frac{\delta \mathcal{F}}{\delta P_n} = 0$

Partial differentiation with respect to P_n yields

$$\frac{dF_n}{dP_n} - \lambda + \lambda \frac{\delta P_L}{\delta P_n} = 0$$

for minimum total fuel cost

$$\frac{dF_n}{dP_n} + \lambda \frac{\delta P_L}{\delta P_n} = \lambda$$

$$\frac{dF_n}{dP_n} \frac{1}{1 - \frac{\delta P_L}{\delta P_n}} = \lambda$$

$$\frac{dF_n}{dP_n} L_n = \lambda \qquad \ldots\ldots(12)$$

where L_n is called the penalty factor of plant n

and

$$L_n = \frac{1}{1 - \frac{\delta P_L}{\delta P_n}} \quad \ldots\ldots \quad (13)$$

The multiplier λ is Rs per megawatt hour when fuel cost is Rs per hour and power in megawatts. Minimum fuel cost is obtained when the incremental fuel cost of each plant multiplied by its penalty factor is the same for all points in the system.

4.11 Plant Scheduling Considering Losses:

This is done by coordinating the incremental cost of generation with the transmission loss incurred in the delivery so that the cost of delivered power is equal at every point on the system. It is reasonable considering that the cost of generation plus delivery can be exactly paralled to the case neglecting losses where we have the cost of generated power equal at every point on the system. With no losses we are assuming the system load on the generation buses, with loss there is an expense in delivery which we should include with the cost of generation.

Let us consider a system as shown in the fig. 4.5 consisting of two sources and one transmission line. For economical operation the cost of delivered power should be the same at that point from both the sources.

$$\text{i.e.} \quad \frac{dF_1}{dP_1} L_1 = \frac{dF_2}{dP_2} L_2 = \lambda$$

where L_1 = penalty factor of Plant 1 = $\dfrac{1}{1-\dfrac{\delta P_L}{\delta P_1}}$

L_2 = penalty factor of plant 2 = $\dfrac{1}{1-\dfrac{\delta P_L}{\delta P_2}}$

The total losses in the system P_L is given by

$$P_L = P_1^2 B_{11} + 2P_1 P_2 B_{12} + P_2^2 B_{22}$$

where P_1 and P_2 are the station out puts and B_{11}, B_{12} and B_{22} are loss coefficients (self and mutual constants obtained from the mathematical model)

The incremental loss incurred in delivering the increased out put from sources 1 and 2 is given as follows:

$$\frac{\delta P_L}{\delta P_1} = 2P_1 B_{11} + 2P_2 B_{12}$$

$$\frac{\delta P_L}{\delta P_2} = 2P_2 B_{22} + 2P_1 B_{12}$$

From the incremental loss it is necessary to calculate the penalty factor multiplier $\dfrac{1}{1-\dfrac{\delta P_L}{\delta P_n}}$ which is used to modify the incremental cost of power $\dfrac{dF}{dP}$ for the two machines.

We have to solve the above non-linear simultaneous equations for obtaining the incremental losses in the transmission lines. As we increase the number of stations or variable sources, the number and size of equations increases proportionately. The time required and complexity of solution increases tremendously.

Since the out put of individual stations generally affects the delivery loss incurred by all other stations with a transmission system other than radial, any deviation of station out puts from those scheduled will cause errors in the loss portion of our calculations as well as the modified generation costs. with an incremental slide rule or the equipment, the machine incremental cost portion could be quickly calculated. But to complete the job we need new transmission loss penalty factor multipliers to readjust the machine cost curves. The calculation of these penalty factors by hand would be too time consuming to be practicable. As such penalty factor computors are used to calculate the above penalty factors.

With either manual or automatic input to a penalty factor computer, the despatcher is provided with an inexpensive means for rapid, accurate calculation of penalty factor multipliers, necessary to include the effect of transmission line losses in the generation schedules. The penalty factor computer with an incremental loading slide rule the incremental cost of delivered power can be scheduled.

4.12 Economic Operation of a Combined steam and Hydro Electric power systems.

An important problem in the system operation of a combined steam and hydro electric power systems involves the determination of the out puts of both the hydro-electric and steam electric sources for over all system efficiency.

The short range economic optimisation schedule of steam and hydro electric plants is given by the following coordination equations.

$$\frac{dF_n}{dP_{sn}} + \lambda \frac{\delta P_L}{\delta P_{sn}} = \lambda$$

$$\gamma_j \frac{d_{wj}}{dP_{Hj}} + \lambda \frac{\delta P_L}{\delta P_{Hj}} = \lambda$$

where $\frac{d F_n}{d P_{sn}}$ = Incremental production cost of steam n in Rs/ Mwhr.

$\frac{\delta P_L}{\delta P_{sn}}$ = Incremental transmission loss of steam plant n

$\frac{d w_j}{dP_{Hj}}$ = Incremental water rate at hydro plant j cft per Mw.

$\frac{\delta P_L}{\delta P_{Hj}}$ = Incremental transmission losses of Hydro plant j

λ = Incremental cost received power in Rs per Mwhr

γ_j = Water conversion coefficient which converts incremental water rate into equivalent incremental plant cost.

The conversion coefficient γ converts the incremental water rate into an equivalent incremental plant cost and consequently determines the volume of water used.

When the effect of head variations are neglected, the water conversion coefficient γ is contant for the period. considered. When head variations are significant the water conversion coefficient becomes a function of time. The effect of this variable γ maintains the reservoir elevation high early in the time period to utilize the inflow at the highest head possible consistent with the balancing economic factors of incremental water rate and incremental production cost.

It is often considered good practice to operate hydro plants near the point of maximum efficiency except during the times of surplus water. The following are the two alternative methods of scheduling associated steam plants.

a) steam plants scheduled by equal incremental plant costs.

b) steam plants scheduled by coordination equations.

4.13 Penalty Factor Computers.

The large amounts of power that are interchanged over transmission lines within and between large utilities require accurate calculation of incremental transmission line losses for the most economic operation.

The incremental losses in terms of penalties on the sources of generation can be calculated more accurately using penalty factor computer. These penalties account for the effect of incremental losses in transferring generation from each source to the load. The penalty factor computer calculate the incremental losses associated with each source of generation for each given total system load.

The penalty factor and the incremental transmission losses can be represented by the following mathematical equations.

$$\text{Penalty factor} \quad L_n = \frac{1}{1 - \frac{\delta P_L}{\delta P_n}}$$

$$\text{Incremental transmission loss} = \frac{\delta P_L}{\delta P_n} = \sum_m 2 P_m B_{mn} + B_{no}$$

It is necessary to solve the above equation for each source and when more than 3 or 4 sources are involved this becomes an extremely time consuming task.

Using analoge penalty factor computers we may get the penalty factors on a long scale indicator by setting source powers manually.

The source powers are represented as a.c. voltages with a scale of 0.5 volts per MW while B_{mn} coefficients are potentio meters across which the voltages proportional to the source powers are impressed. A split secondary transformer allows the selection of an opposite polarity voltages to represent negative B_{mn} coefficients. The out put of these potentio meters are summed as currents through individual dropping resistors and read selectively by means of a servo-type indicator.

Fig. 4.7 shows a schematic diagram of a representative two source manual penalty factor computer.

Automatic penalty factor computers are an integral part of the General Electric Automatic despatching system, when transmission losses are an important consideration to the utility. It receives input from the ties and stations and computes the resulting penalty factor. In addition it automatically modifies (i) by appropriate penalty factors, (ii) the master area signal which is sent to control stations.

An analogue computer developed cooperatively by the American Gas and Electric Service Corporation and the General Electric Co. was intalled in the Central production and coordination office of the American Gas and Electric Service Corporation early in 1955, operates inconjunction with an incremental fuel cost slide rule[9].

4.14 Complete Automatic Despatch Computer.

The additional units incorporated in the computer shown in fig. 4.8 compared to the computer shown in fig. 4.4 are divider units and penalty factor computer unit(10). The divider units divide the cost level (cost of delivered power) by the penalty factor multipliers to satisfy the condition of coordination equation where the cost of delivered power is equal to the station incremental cost times the penalty factor. The inputs to the penalty factor computer are shown in the fig.4.8. The output of the penalty factor por- tion of the computer, the penalty factor multipliers for each station and any important tie points. The penalty factor for the station feed into the divider units to automatically modify the incremental cost levels seen by the station.

The penalty factor computer portion calculates the penalty factor multipliers from non-linear simultaneous equations mentioned earlier.

The use of the complete automatic despatching computer when preparing generation schedule would require the tie line power flows the non conforming loads and uncomputed station outputs to be set manually.with this done for a certain range of system load or period of time on the schedule, the only further adjustment necessary is a setting for the system load.

For each system load the despatching computer will calculate the machine and the station outputs including the effect of losses. It provides the information necessary to prepare a complete generation schedule once the decision has been taken as to what machine should be operated and when.

4.15 Automatic Despatching Computer-Controller.

An automatic despatching computer-controlled arrangement can be in either of two basic forms, as an independent computer which provides information for the controlled system or a combined computer and system control. The first is a despatching computer with telemetered input information and the output tied into the system control. The second is a combination of computor and system control.

To convert a despatching computer into controlling computer the important inputs to the computer and out put information must be automated.

The computer out puts, the machine or station generation values, must be compared with the telemetered information on the actual machine or station generations. Any differences between the computed and actual generation is used to initiate control automatically. Ideally the computer should be calculate and control the output of individual machines. This would require a separate control channel from the despatching office to each machine. In mos case the cost and the availability of channels for such an arrangement would rule out this possibility. The other alternative station out puts computed and controlled requires only one channel to each station. This arrangement requires a duplication of computing equipment at the despatching office and at each station. The station equipment is required to allocate the computed station out put among machines. The machine characteristic set into the station equipment must be exactly duplicate those set into the computer at the despatching officer if optimum economy is to be realised. Differences between the station and despatching office machine characteristic could cause considerable deviation from the optimum machine outputs.

The G.E. Automatic despatching system combines the computer controller functions with the system control. Both the computer controller function and the system controller are accomplished over a single channel to each station.

The economic loading portion of the G.E. automatic despatching equipment is shown in fig.4.9. There are two differences between the arrangement of equipment compared to figure 4.8. First the cost unit is driven directly from the system information (Tie Line and frequency deviation) and second the function generators for each machine are not located in the stations eliminates the duplication of equipment and the problem of accurately representing the machine incremental curves at the despatching office as well as at stations. The transmission loss penalty computer portion is unchanged and still computes penalty factors for each station. These penalty factors are used in the same manner as before to modify the cost seen by the stations.

4.16 Automatic Despatching System.
(A Computer-controller)

Fig. 4.10 shows the components of G.E. automatic load despatching system installed at Kansas Power & Light Co., U.S.A.

A computer-controller will not only regulate the system generation to match the changes in load but also allocate these changes in most economical manner. The G.E. automatic despatching system is such a device. This system combines the functions of load-frequency control and economic loading of generating units on an incremental cost basis. The control performs the routine and repetitive functions that eliminate the need for detailed loading schedules and requires a minimum attention from despatcher and station operators. The system uses load frequency control equipment as a basic building block to which can be added economic incremental loading equipment and transmission loss loading equipment as they are needed.

The combination of above three blocks forms a computer controller which will automatically regulate generation to match system load and in addition will operate the system at the lowest possible cost.

The controller block at the left of the drawing No. 4.11 shows both a reset and a proportional controller. The purpose of these two controllers is to provide maximum response upto a safe limit, with limited response beyond this level. The proportional controller is the high speed unit and it is capable of correcting a rate of upto 100 per cent of capacity per minute. Of course it is impossible to instantaneously move a machine more than approximately 15 per cent [11] from its operating point due to the limitations of the boilers and the turbine itself. Therefore the proportional controller has stops which limits the amount of change it can require from the system. The reset controller has a slower maximum rate of 5% per minute and it is not limited as to the amount of capacity it can swing. Note that the two signals are then combined into one control signal which is then sent to the stations.

Fig. 4.12 shows the combined out put of the reset and proportional controllers. The proportional controller (curve B) responds very rapidly to wipe out the area requirement signal. The reset action (curve A) moves along a much slower rate. Their combined action results in correcting the area requirement as rapidly as the characteristics of machines will permit. The slope of curve B will vary with the size of the requirement signal- that is, it will respond more rapidly to a large signal than to a small one. Also the knee point of the curve can be adjusted by the despatcher so as to take anywhere from 50 to 90 per cent of the area requirement signal instantaneously leaving the remainder for the reset controller.

4.17 Economic Operation of Inter-connected areas:

For optimum economy incremental cost of received power should be the same from all sources.

There are number of approaches to the problem of obtaining economic operation of several interconnected areas. Computer controllers are best suited for controlling simultaneously area frequency, area net interchange and economic allocation of generation within the area. The net interchange out of the area is set manually and is determined by contracts and bargaining with neighbouring areas.

One approach to obtaining economic operation of the pool formed by the ineterconnected areas is to treat the several areas as one area. This alternative involves the use of a centalised computer to serve the pool formed by the area. This computer would require knowledge of all plant loading and external and internal flows and the control system would require a control channel to each plant.

Another approach would involve application of automatic despatching system to the individual areas with means of determining automatically the economic interchange between the areas. Each area would require a knowledge of the plant loads in the area and the interconnection flows out of the area in addition to control information instructing the area either to increase or decrease its delivery to the pool. The use of this decentralised approach will in a number of cases offer important advantages over the centralised approach.

1. Reduction in telemetering channel requirements.
2. Use of smaller decentralised computer controllers.
3. Ready availability of information for accounting between areas.
4. The method permits more accurate consideration of transmission losses.

The above advantages are more pronounced when number of tie points between the areas is small.

The proposed decentalised method is based on the following principle : when the incremental cost of delivering power to any particular point in given group of areas is the same from all sources, the power pool formed by the area is in economic despatch[12].

4.18 Multi-area Economic Despatch Computers.

A multi-area despatching computer accomplishes the following tasks which are not previously under taken by an single area despatch computers.

i) Calculation of economic inter change between areas.

ii) Calculation of weighted incremental costs at boundaries for inter connection accounting.

iii) Calculation of incremental costs of wheeling losses.

iv) Calculation of flows over individual areas.

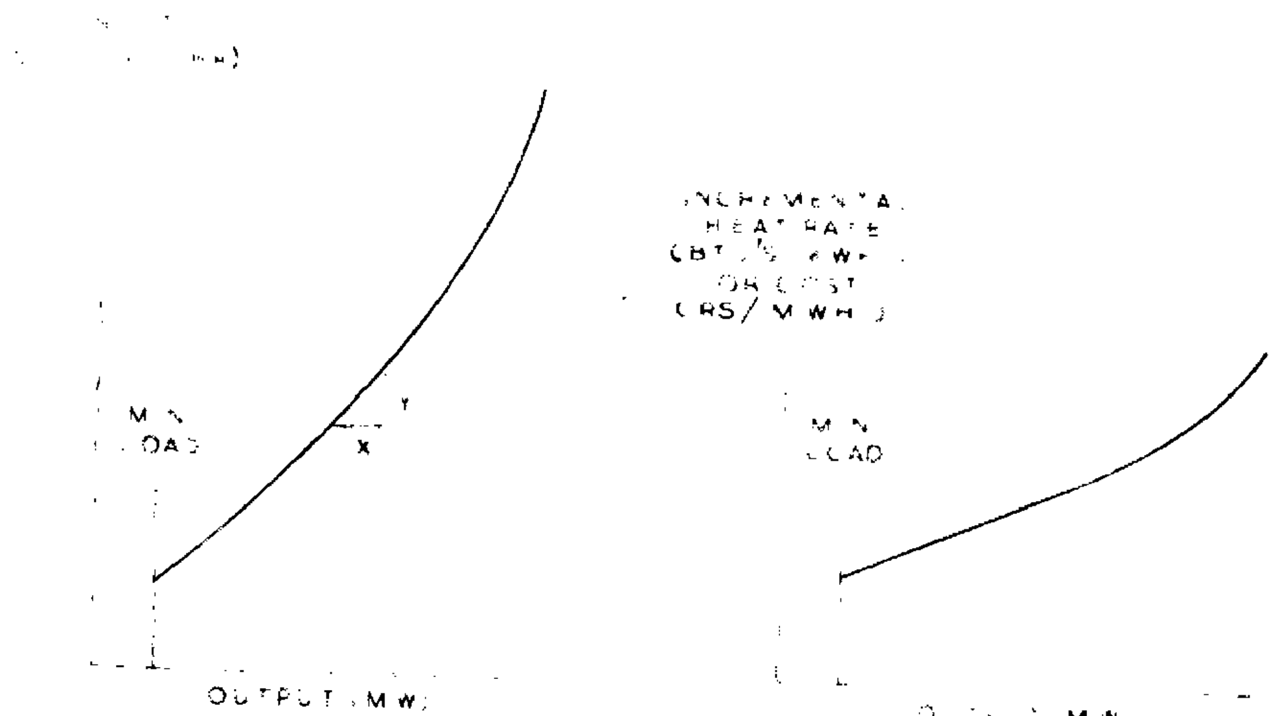
The Niagara Mohawk Power Corporation and the New York State Electric and Gas Corporation have installed the multi-area computer in Syracuse, New York for the economic operation of the above systems. This computer will be used for interconnection dealings between Niagara Mohawk, New York State Electric and Gas and their inter connected neighbourers. This multiarea despatch computer is based on the use of each individual area together with supplementary devices which determine the economic interchange between areas and the flows over the individual tie lines.

The multi-area Economic despatch computers will do economic allocation of the generation in each area in addition to the said duties.

4.19 Southern Regional Power Systems:

The operation of Southern Regional Power Systems using despatching computers for optimum economy is discussed under Chapter 8.

Further we have seen that speech communication, telemetering, telesignalling are essentially required for operation of systems for optimum economy. Communication facilities required under load despatch scheme are discussed in the next Chapter.



INPUT OUTPUT CURVE

INCREMENTAL COST CURVE

FIG 4·1

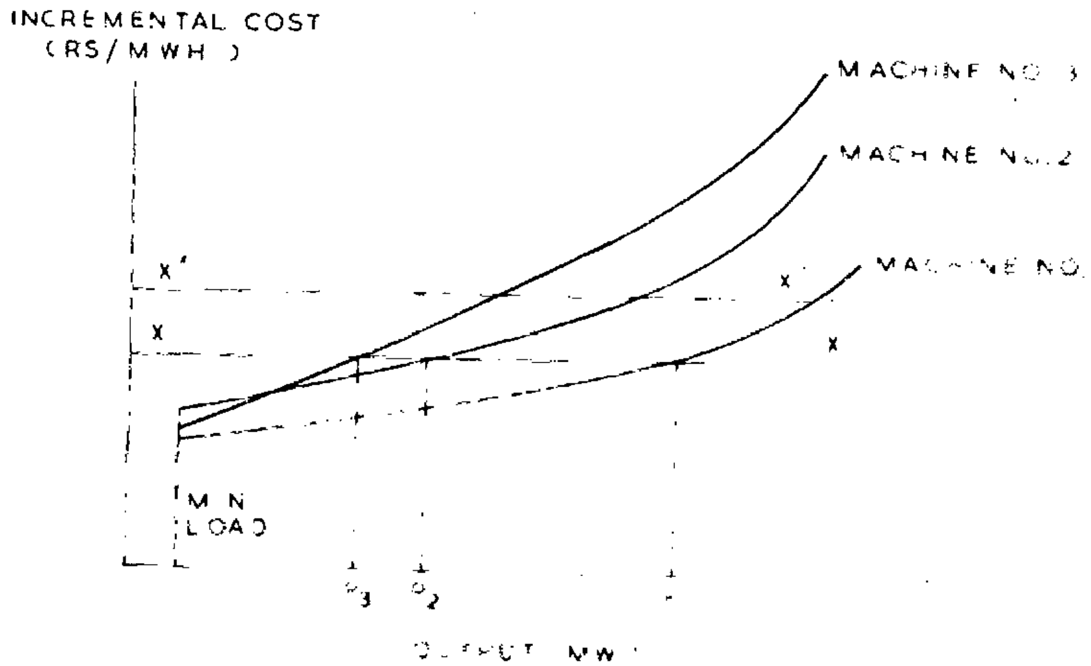


FIG 4·2 LOADING AT EQUAL INCREMENTAL COST

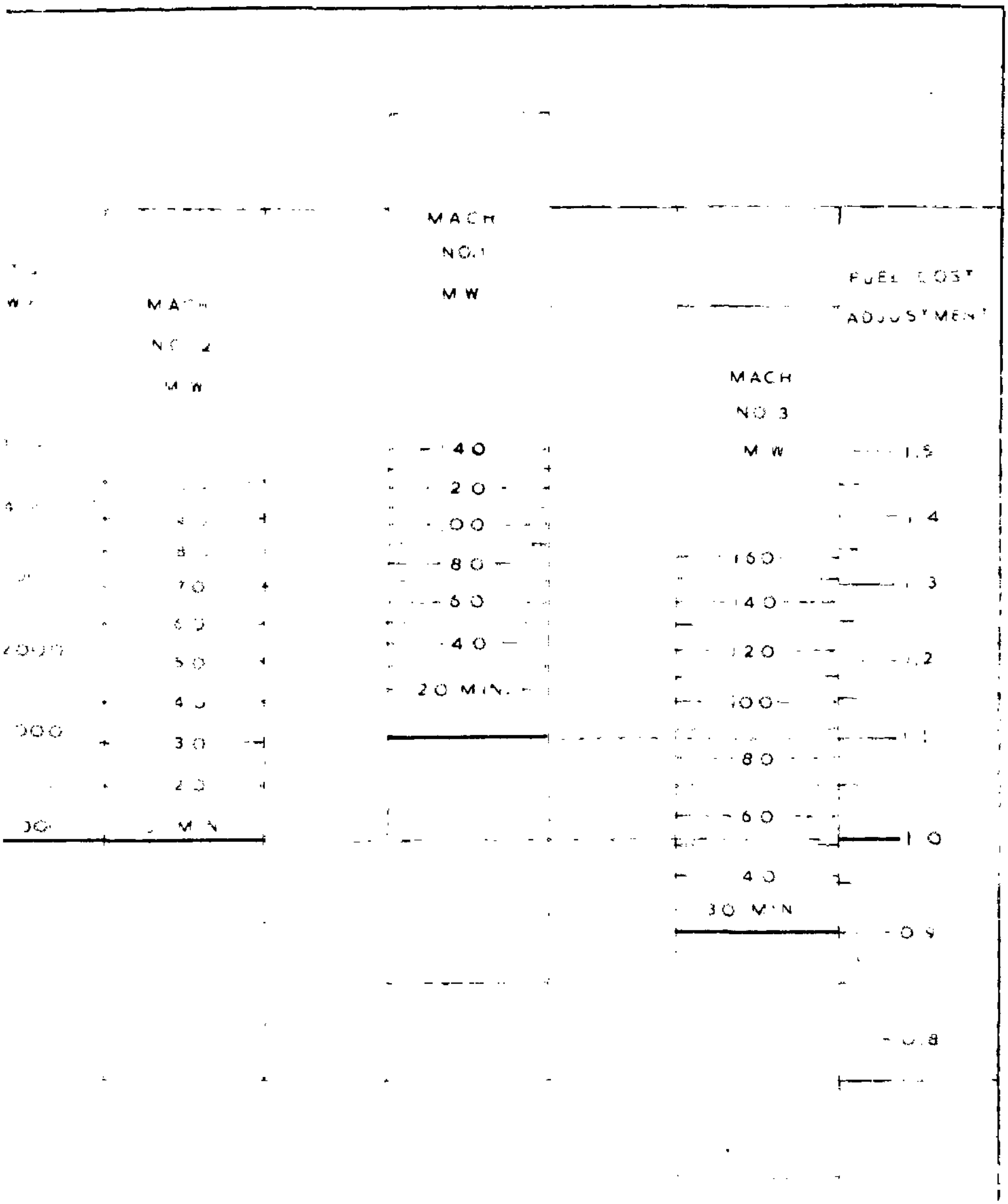


FIG. 4.3 INCREMENTAL LOADING SLIDE RULE

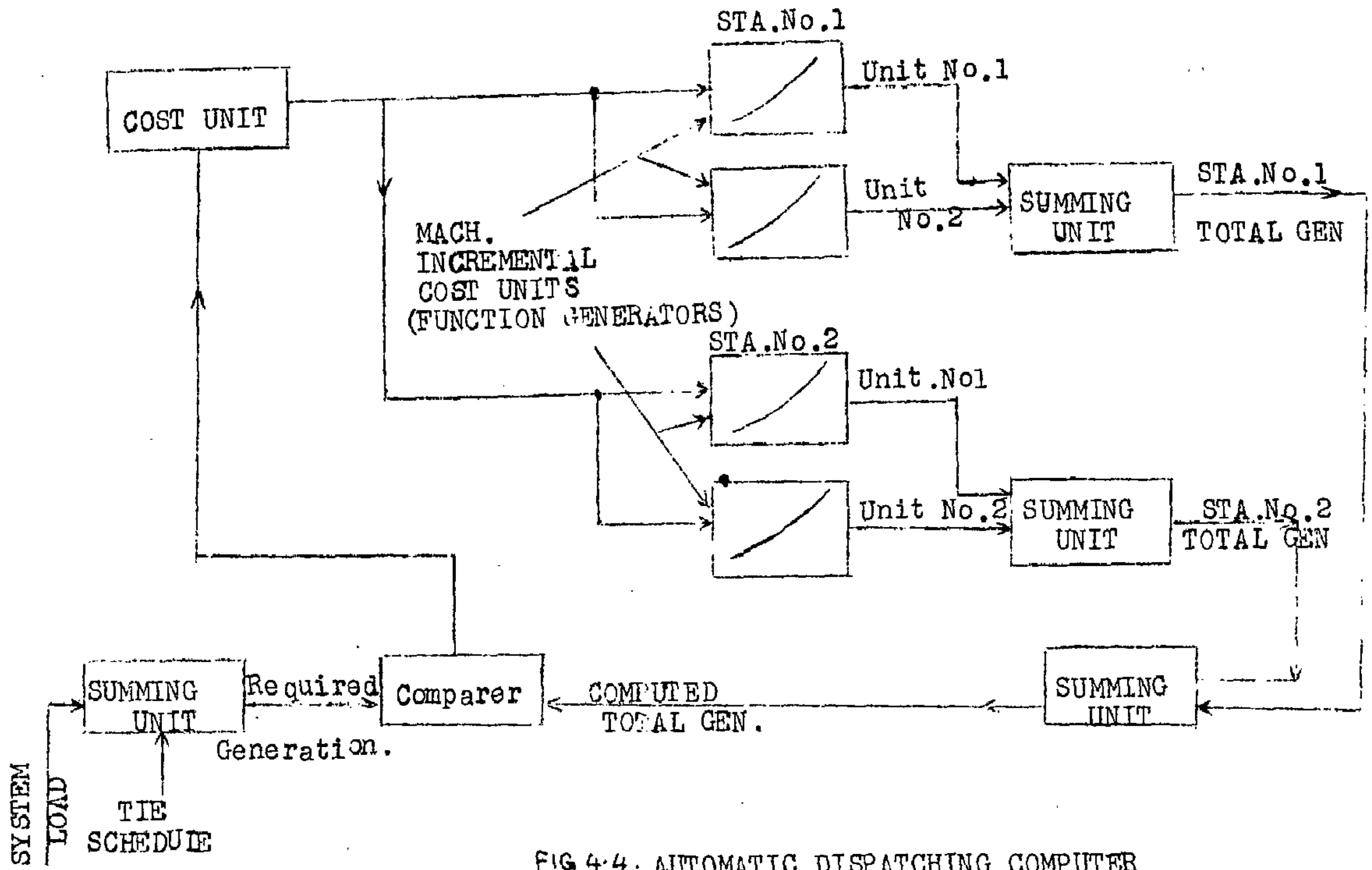


FIG 4.4. AUTOMATIC DISPATCHING COMPUTER
(NEGLECTING TRANSMISSION LOSSES)

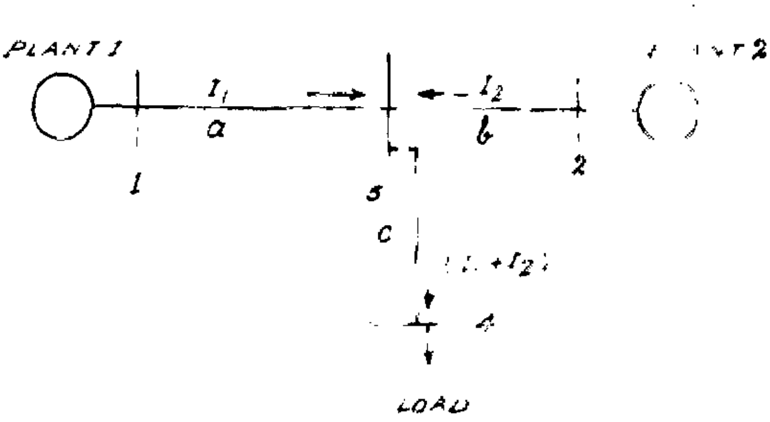


FIG 4·5 SYSTEM CONNECTING TWO GENERATING PLANTS TO ONE LOAD

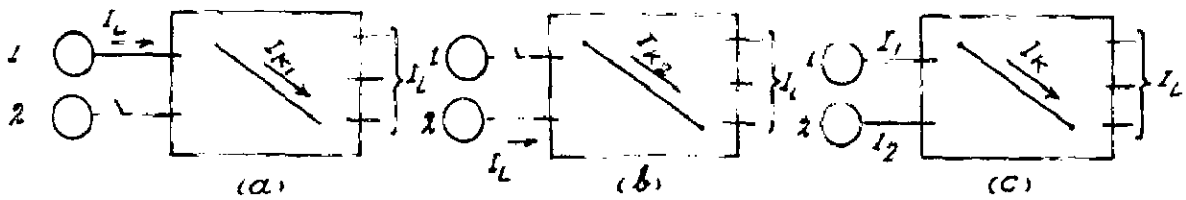


FIG. 4·6 TWO GENERATING PLANTS CONNECTED THROUGH AN ARBITRARY NETWORK TO ANY NUMBER OF LOADS

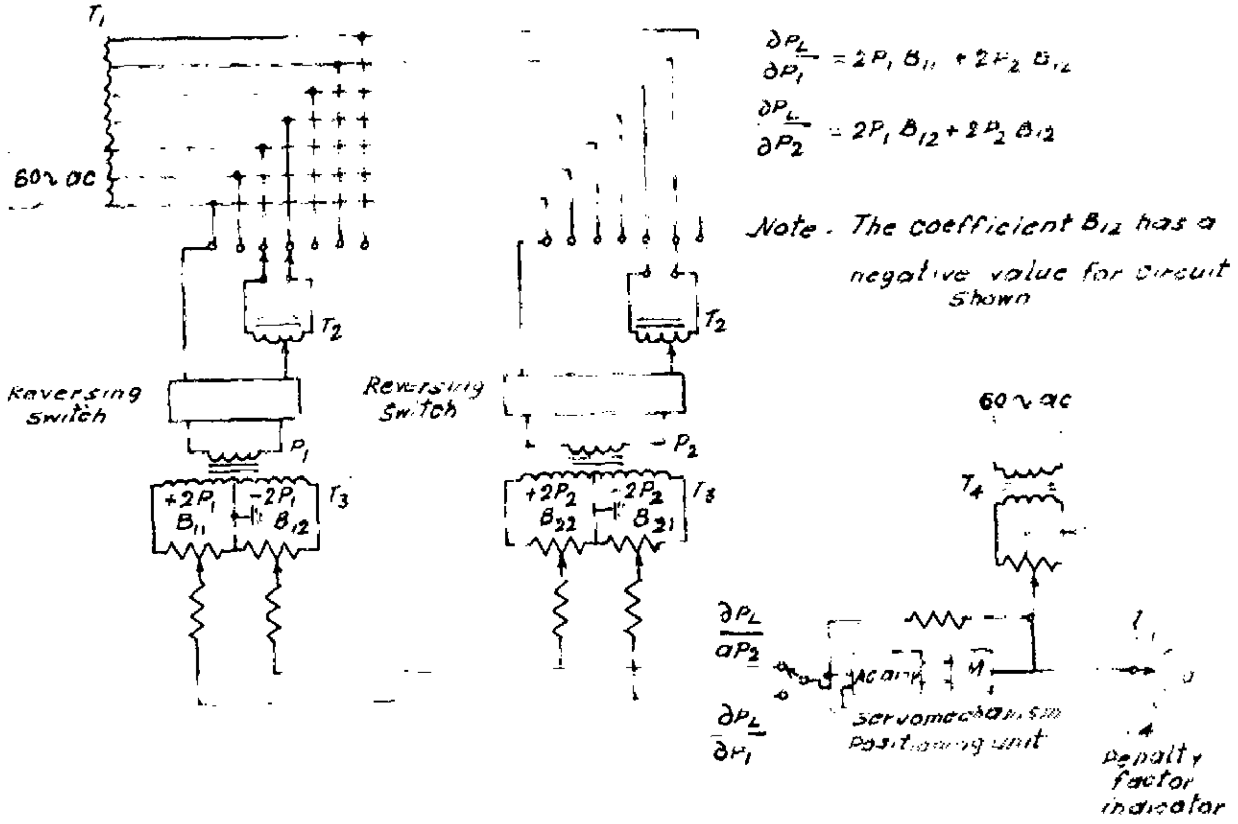


FIG 4·7 SCHEMATIC DIAGRAM OF TWO SOURCE PENALTY FACTOR COMPUTER

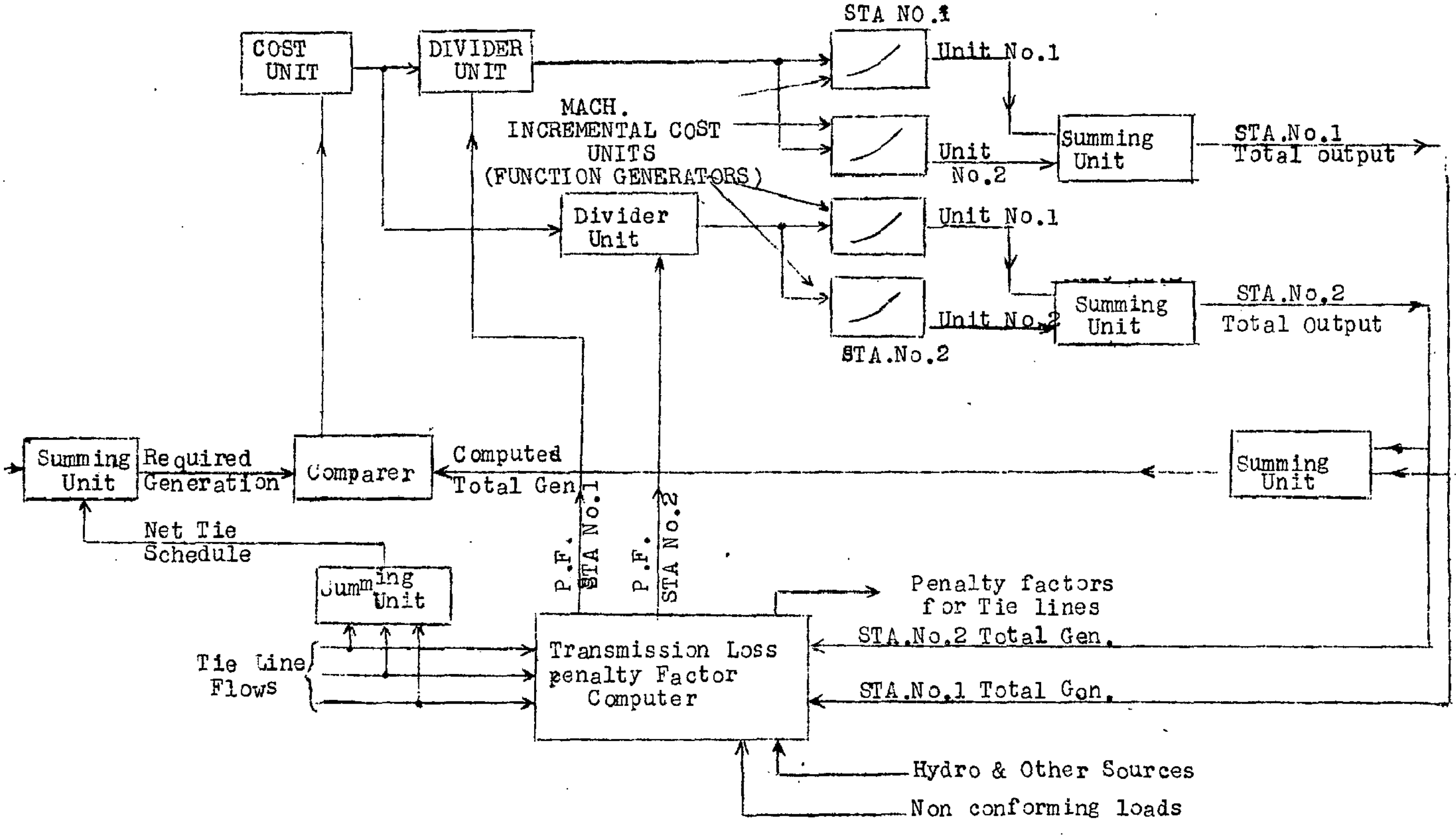


FIG 4.8. COMPLETE AUTOMATIC DISPATCHING COMPUTER

FIG 4·9. ECONOMIC LOADING PORTION OF GE AUTOMATIC DISPATCHING SYSTEM WITH PENALTY FACTOR COMPUTER

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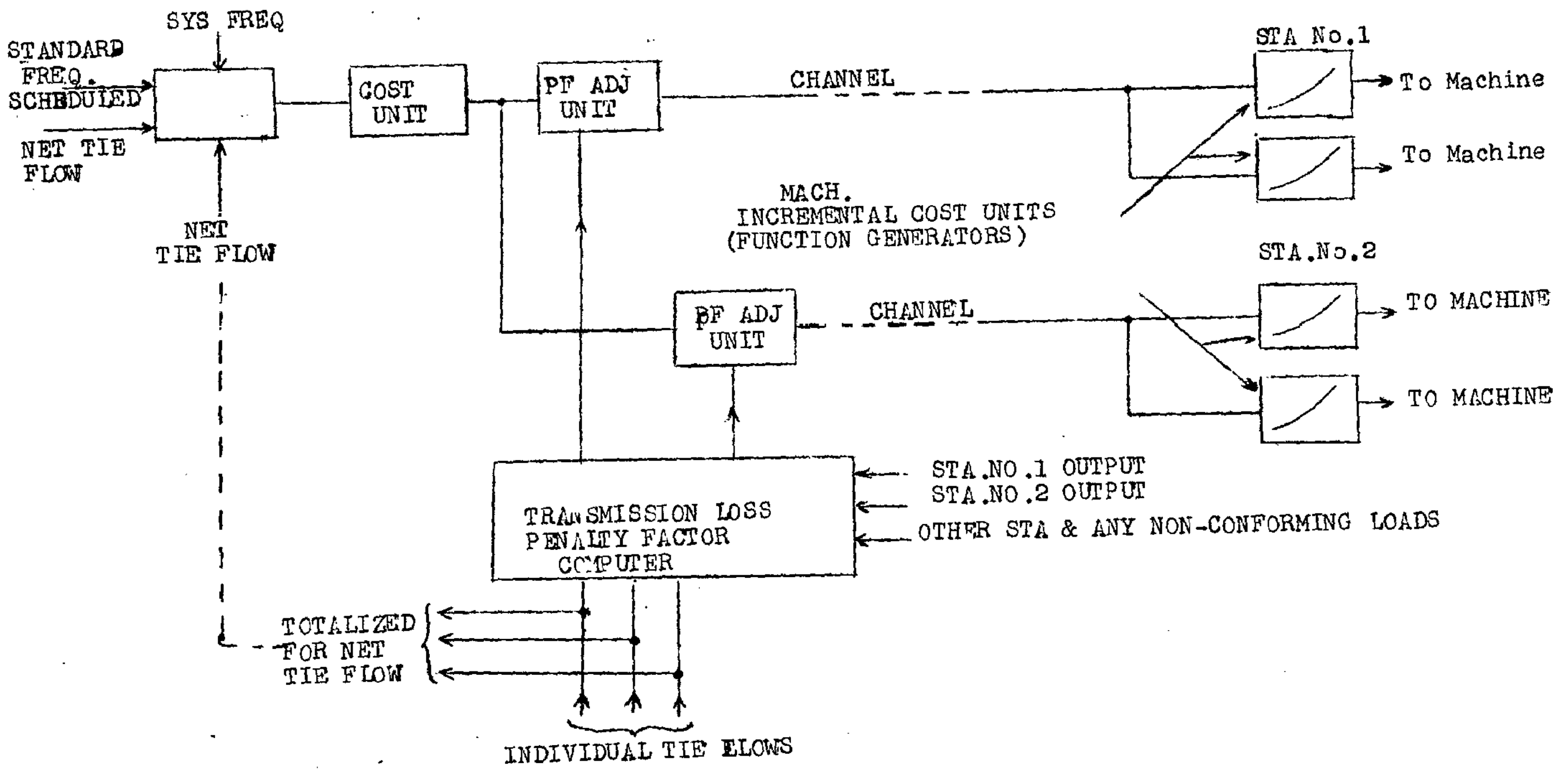


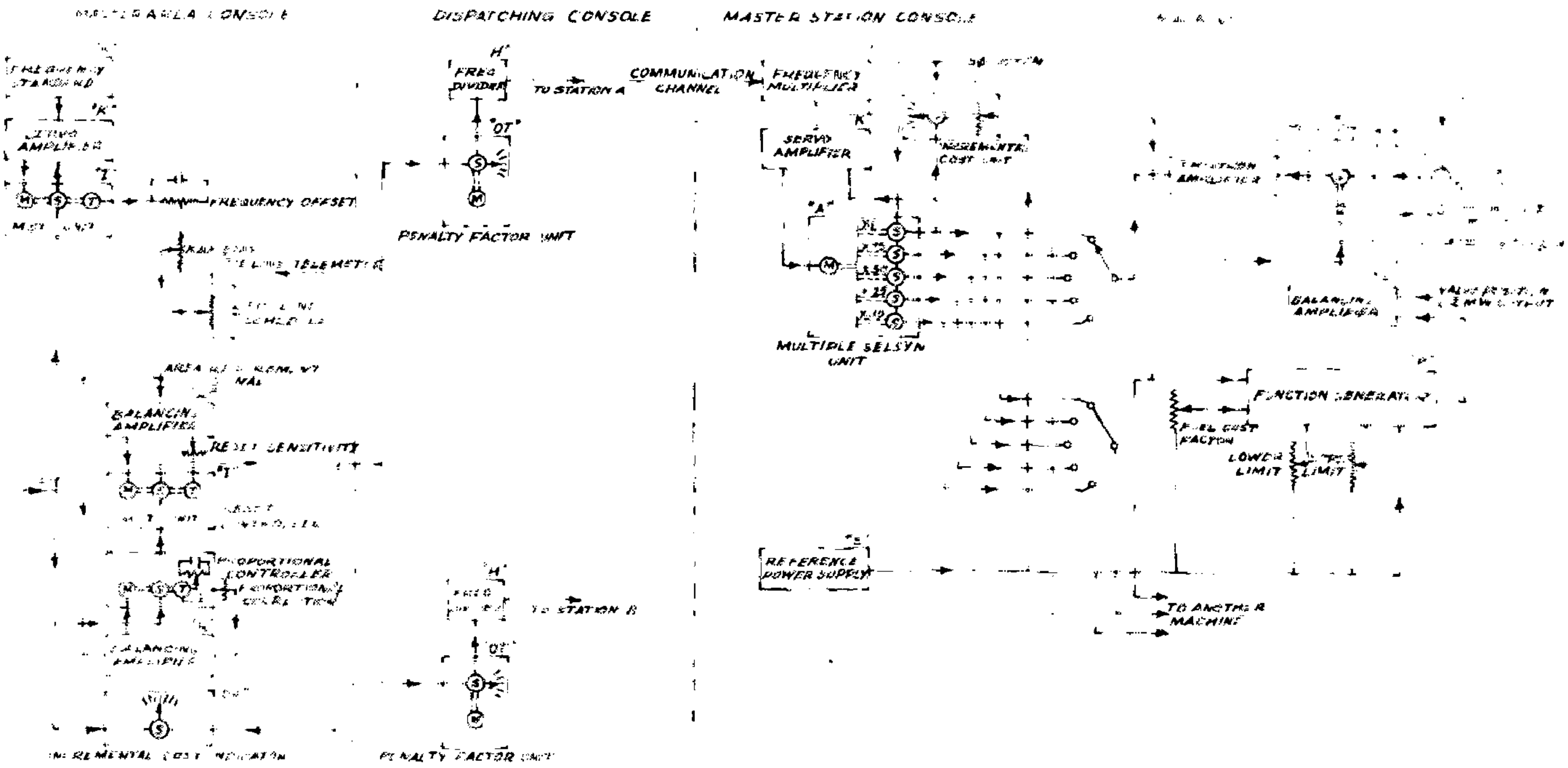


FIG 4.10. BLOCK DIAGRAM OF A TYPICAL SYSTEM

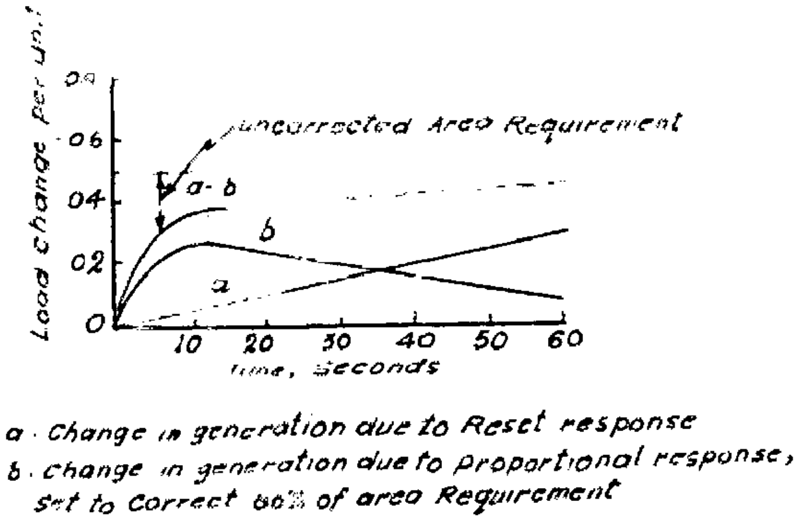


FIG 4.12 . COMBINED OUTPUT OF RESET AND PROPORTIONAL CONTROLLER

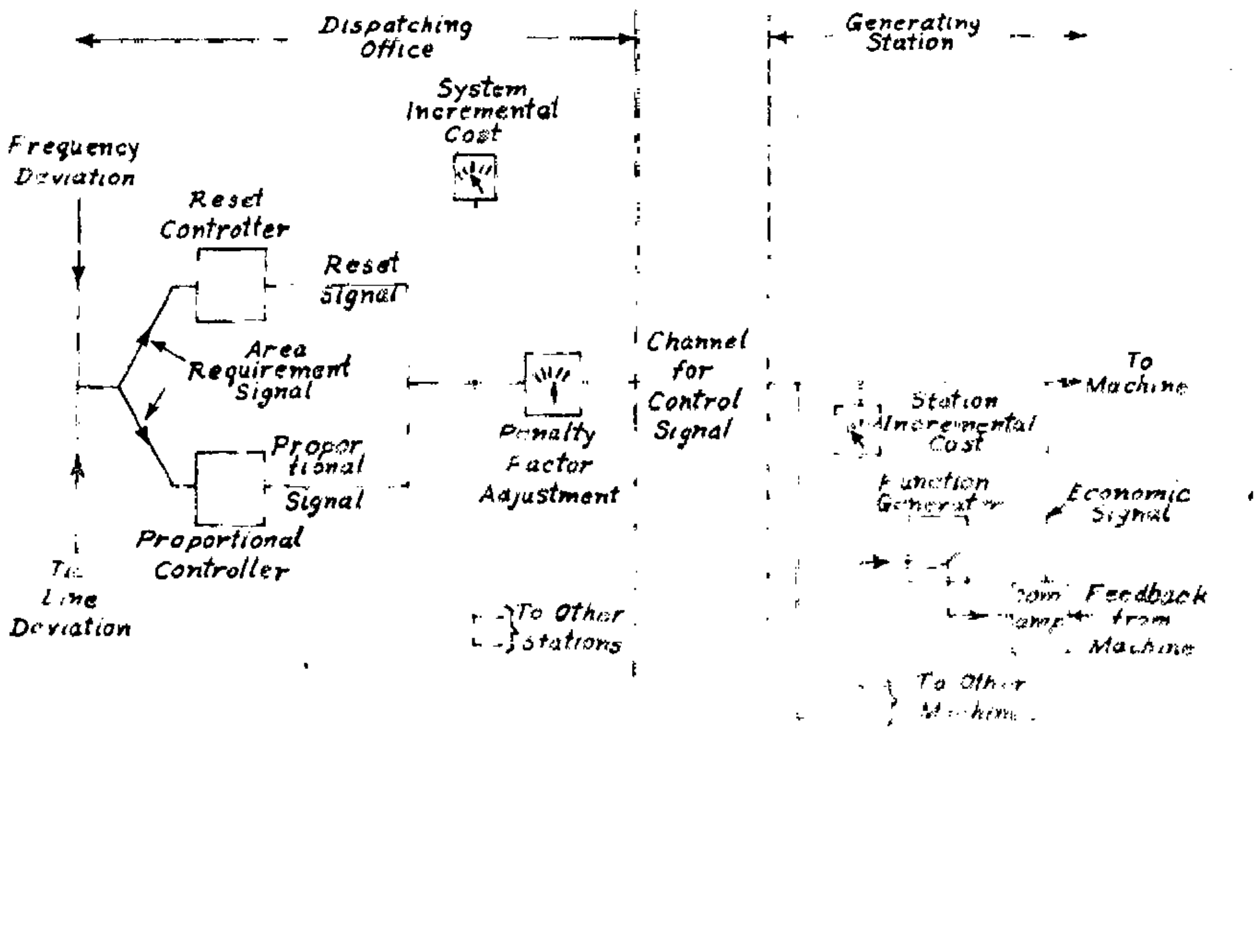


FIG 4.. DESPATCHING COMPUTER RESET AND PROPORTIONAL CONTROLLER

CHAPTER - 5

COMMUNICATION IN LOAD DESPATCHING STATION

5.1 Development of a well Knit Communication network assumes considerable importance in power systems, since reliable communication play a important role in the satisfactory functioning of the integrated and the inter-connected power systems. The communication facilities such as speech, telemetering, teleprinting and telesignalling are most vitally required by the load despatcher. The communication facilities should be provided on nearly 100% reliable basis so that the load despatcher would be in a position to discharge his functions smoothly and uninterruptedly. Nearly 100% reliable communication can be achieved by providing communication facilities on primary cum back up basis. That is t [illegible] ; the back up system provided on different route would be readily available to the despatcher enabling him to carryout his functions normally.

Power line carrier link is used for variety of functions such as voice communication, relaying, telemetering, supervisory control, teleprinting etc. Today power line carrier is indespensable to the operation of most power systems. Power line carrier offers rapid and dependable communication for load despatching. carrier relaying permits high speed clearing of all types of faults with an increase in stability limits and permissible line loading. Carrier provides economical channels for telemetering of continuous system particulars to despatcher for efficient system operation. Carrier channels are used for remote supervision and control of many important sub-stations and for automatic load control of numerous large generating units.

Power utilities in India have till now mostly using power line carrier for the above said purposes. Though the power line carrier proved to be satisfactory and economical, they have certain inherent limitations such as following

i) where the signals have to pass through more than 4 to 5 line sections, dependability of communication is very much reduced since the signals become weak and nosiy..

ii)the probability of finding some intermediate circuits engaged, increases as the tie line sections are more than 4 or 5.

iii) the problem of frequency allocation in certain sections becomes increasing difficult as to network develops.

iv) further some of the places are not connected by power lines.

Hence in the development of grid networks, the need for exploring alternative means of communication becomes necessary.

A number of power systems on the continent and in U.S.A. and Canada are making use of P and T facilities to a considerable extent. In French system about 60% of the communication lines comprises of P & T circuits, whereas in British grid the P and T circuits comprises over 80% of the total communication circuits[12], utilisation of P.L.C.C. and P and T facilities in tandom is a very common feature in number of countries.

In India most of the cities are interconnected (or being connected) by coaxial cable with a capacity of 960 or more channels[12] by P and T authorities. Each channel can accommodate 18 sub-channels for telemetering, telesignalling etc. plans for installation of microwave link between major cities as an alternative means of communication are also under implimentation.

The advantages of P and T facilities are as follows

1) Since transmission is through underground coaxial cable or through microwave links, they are more reliable than transmission through open wire circuits which are liable for various physical disturbances.

ii) Automatic transfer from coaxial cables to micro links and vice-versa is possible whenever fault occurs on one of the two above links and thus greatly enhance the reliablity of communication system.

Under the above circumstances it is desirable that the P and T facilities being established in the country should be fully utilised along with P.L.C.C. for obtaining 100% reliable communication.

5.2 Functions of carrier channel:

Brown Bovery Transistorised single side band carrier equipment type ETL A and [illegible] are suitable for carrier frequency range varying from 35 Kc to 460 Kc[14] (500 Kc).

Power line carrier is used for simultaneous transmitting of various signals such as telemetering, control, carrier relaying etc. over a single channel, and usually several carrier channels on the same line can make joint use of coupling and tuning equipment. Such efficient use of carrier often justifies an investment in the apparatus that might not be justifiable for a single function alone.

Many functions that require the transmission of intelligence in the form of impulses, such as telemetering, load frequency control can be performed simultaneously over a single carrier frequency by modulating the carrier with audio-frequency tones. Each tone frequency is in effect a separate carrier channel itself using the radio frequency carrier channel as its conductor. At the receiving end of such a channel, separate tone receivers are operated from the output the radio frequency receiver, each individual tone receiver being tuned to receive one particular tone and reject the others.

If a continuous telemetering and simultaneous communication are required then separate filters are used to separate the tone frequencies from the speech at the sending and receiving ends.

5.3 Modulation:

Amplitude modulation is most widely used in power line carrier communication system. Amplitude modulation is a variation of amplitude of the carrier currents in accordance with the variation of a speech wave. Actually in this case the resulting currents consist of a mixture of carrier current and currents of the so called side-bands.

The side bands consist of the carrier frequency minus the modulating frequency of the speech at that instant and the carrier frequency plus modulating frequency of the speech at that instant. More refined modulation techniques are available by using combination of circuitory and filters, the most common is single side band technique in which only one side band is transmitted eliminating both the carrier and unnecessary complementary side band. Since all the intelligence is carried by one side band this saves frequency space and power transmitted over the circuit.

The frequency modulation (f.m) system is also used in P.L.C. work. In this system amplitude or intensity of the transmitted signal is constant and the frequency varies above and below a reference frequency in accordance with the intelligence being transmitted.

The frequency shift system is a special form of frequency modulation that is used for telegraphic functions such as telemetering. In this system the two closely spaced frequencies are used. A continuous carrier wave of constant amplitude is shifted back and forth between the two frequencies, one frequency denoting a mark and one a space in transmission of impulses. By using highly stable crystal oscillators for the transmitted frequencies and correspondingly stable and highly selective circuits in the receivers, it is possible to place the mark & space frequencies within 0.06 percent[15] of each other in carrier spectrum. Even with this spacing, the equivalent F.M. deviation ratio with the slow-speed keying required by practical impulse telemetering systems is extremely high with the result that a properly designed frequency shift system can provide sub-stantial gains in signal to oice ratio with a small transmitted band width.

5.4 Carrier Telemetering:

The quantities often telemetered on power system are electrical quantities usually kilowatts, kilovars, temperature, water level, tap positions and many other can be telemetered. The principle is generally based on converting the indication to be telemetered into pulses of a definite character, a variation in the telemetered quantity being reflected as a variation in some charact-erstic of the transmitted pulse.

In the impulse rate system, the frequency or rate of pulses varies in proportion to the magnitude of the telemetered quantity. A reference or a base rate of impulsing represents a magnitude of zero, impulse rates above the base rate represent positive increments in the quantity and impulse rates below the base rate represent negative increments.

In impulse duration system the frequency of the pulses is constant. The duration of the pulse during a complete pulsing cycle is proportional to the magnitude of the telemetered quantity.

The pulse telemetering systems are well suited to operation over carrier channels. The fact that the intelligence transmitted takes the form of a simple pulses makes it possible to use in many applications a simple carrier assembly in which unmodulated carrier is turned on and off by a pair of contacts controlled by the telemetering device. No special modulation schemes are necessary with these systems and the accuracy of the received information is independent of variations in the attenuation of the channel over which it is transmitted.

The channel requirements for impulse telemetering systems are relatively simple and because transmission alone or reception alone is usually required, the assemblies used for telemetering purposes are often correspondingly simple. If a single set of impulses is to be transmitted from a given point, the assembly often consist of a single frequency shift carrier transmitter with self contained a.c. power supply. The carrier frequency output of the transmitter is controlled directly by impulse forming device which shift the output back and forth between the mark and space frequencies as its contacts close and open.

At the receiving end of a such a channel a frequency shift receiver is used to receive the carrier signal. The receiver operates a relay which in turn keys the impulse receiver.

In application where more than two or three quantities are to be telemetered from a single point simultaneously it is common practice to use audio tone transmitter units to modulate the carrier frequency signal. One tone frequency is used for each telemetered quantity and the carrier wave is left on continuously.

5.5 Speech Channel.

It is preferable to have the following types of express speech channels between regional load despatching station to all state load despatching stations and from state load despatching stations to important grid and power stations.

Channel 1: The first category of the express channel should be provided with push button type of calling facility. These channels could be accommodated in the P.L.C. link. Because push button facility no outside person can enter into these channels thus ensuring exclusive use of these channels by the load despatcher themselves.

Channel No.2 The second category of express channel should be provided with dialing type of calling facility with priority keys located only on the despatchers telephone. These channels could be accommodated using P and T coaxial/microwave links (as a back up, in initial stages). Because of dialing facility these channels could also be used by the scheduling and other staff of despatching station whenever not being used by the despatchers. On the outage of the despatchers channel (i.e. express channel with push button facility) either due to route outage or terminal equipment outage this channel could be used exclusively by the despatcher by making use of priority key facility thus acting as back up of the despatchers channel, thereby ensuring optimum use of the leased P and T channel.

From the state load despatching station to the important grid and generating stations where P and T facilities are not available it is preferable to have back up also through P.L.C. link considering route diversity factor.

5.6 Telemetering Channels:

The despatcher needs various values of Mw, MVAr etc. of the generating stations, tie lines and sub-stations proposed to be monitered at the despatching station for smooth discharging the functions. In order to obtain a reliable telemetering plan, it is suggested that the total values of the telemetering be distributed in the two routes (P.L.C. link and P and T coaxial/microwave link). Such distribution of telemetering values will ensure that an outage of any one communication route, only 50% of the values of the total will be lost, while 50% of the total values are available to the despatcher who can carryout the functions with the available values.

However it will also be possible to design to receive 100% telemetered values to the despatching station even under outage condition, if economy permits. One of the methods to achieve 100% reliability in telemetering can be by sending all the total values in primary and back up routes so that even on outage of any one route all the telemetering values will be still available at the despatching stations.

5.7 . Teleprinting Channels.

Teleprinters are required at regional load despatching stations to transmit and receive written messages regarding instructions, data etc. between regional load despatching station and state load despatching stations. For realistic operations it is preferable to have two teleprinter circuits. One teleprinter circuit between regional load despatching station and state load despatching stations may be accommodated in the primary communication system of the regional load despatching station (P.L.C. link), while other teleprinter circuit may be provided on the back up communication system. This ensures continuous exchanges of messages between regional load despatching station and state load despatching stations.

However from state load despatching station to most of the grid and generating stations only one tele-printing circuit, using P.L.C. link will be sufficient considering econonomical aspects.

5.8. The communication facilities used in the region and in the states for power system operations are discussed in the Chapter 8.

The location and the layouts of regional and state load despatching stations are dealt in the next chapter.

CHAPTER - 6

LOCATION, LAYOUT AND ORGANISATION OF LOAD DESPATCHING STATION

6.1 The aspects to be considered for location of state load despatching Stations are as follows

1. The load despatching station should have a reliable telecommunication facility with all important points of the network under its control. Utilities in India mostly relied on P.L.C. link for communication purposes due to its economy and reliability. The economy occurs over long distances where no telephone facilities exist. Then the power line has two fold purpose, power and communication. Transmission lines are of such sturdy construction that they rank next to underground cables in reliability. As such it is preferable to locate the load despatching station close to an important point of the network so that P.L.C.C. facilities are easily available to all important points of the net work. Very often such points are big load centres and consequently may be near a big city or industrial area.

2. 100% reliable communcation is required for the load despatcher to carry out his functions smoothly and uninterruptedly. As such the P and T channels (coaxial and microwave) which afford reliable and economical communication shall be planned for primary or back up communication system. It is preferable to locate load despatching stations as close as possible to place where

a few channels can be hired out for power system operations.

3. The location of load despatch station should be easily accessible by road, rail and if possible by air.

4. The despatch station should be located as far as possible at the head quarters of the Electricity Boards where statistical and commercial organisation of the Board are usually concentrated, makes a quick exchange data and ideas possible leading to a better coordination.

6.2 Location of Regional Load Despatching Station:

The regional load despatching station will normally be located at a place where one of the state load despatching station of the region exists. The primary requirement for loacating the regional load despatching station is the minimum cost of the communication facilities to be established between regional load despatching station and state load despatching stations in the region as well as with the National Load Despatching station. Besides, the location of regional load despatching station will be normally situated in the centre of the region.

6.3 Area Despatching Stations:

As the network develops and becomes more and more complex one state load despatching station alone may not be adequate for discharging the functions effectively and it becomes necessary to provide area despatching stations one for each well defined area and the size of the state load despatching station would then guide and coordinate the activities of the area despatching stations in the State and also control certain important points of the area.

United Kingdom had two tier control till recently (i.e. National and Area control). In order to cope with the rapidly increasing operational problems due to fast expanding of power systems 3 tier control has been introduced (16) (3rd tier at districts). Each area will have 2 or 3 district control centres to be responsible for 132 Kv system and associated generation. Even in India number of area despatching centres are required under the control of state load despatching station for efficient operation of power systems.

6.4 Regional Despatching Station:

The regional despatching station in each region will coordinate the generation programmes drawn up by the constituent state despatching stations in the interest of the region as a whole, keeping in view the surplus/deficits in each system and available inter-state transmission facilities. The regional load despatching station will also help state load despatching stations in solving interstate power problems such as power rates for inter-state exchange etc. It will formulate broad policies to be followed for load despatching and system control and will review and improve from time to time the techniques of load forecasting and data collection for the region.

6.5 Layout of a Despatching Station:

The despatching station whether a state or regional shall be well planned to accommodate the equipments and the staff of the despatching station as detailed below:

Requirements	Accomodation for equipment & staff
1. Space for equipment	Communication, normal and emergency power supply panels, battery and battery changing equipment P & T exchange, Air conditioning equipments off line computer etc.
2. Control Room	Mimic Board, telemetering panels, despatchers consoles, staff on duty, etc.
3. Technical staff	Chief Load Despatcher, Planning Engineers, scheduling staff, computer staff, operation and maintenance staff, teleprinter operator etc.
4. General facilities	Conference room, Library, testing laboratory, retiring room, pantry, record room, store room etc.
5. Ministerial staff	Space to be provided as per the total staff employed.

The layout of Southern regional despatching station is shown in the exhibit 6.1.

6.6 Equipment in a Despatching Station.

A mimic board in the shape of an are made of translucent plastic, depicting the system transmission lines by different types of colours representing different voltage levels is provided. The locations of the generating stations and sub-stations are shown on the board as far as possible in their geographical positions. The board would serve dual functions, firstly, it will provide the despatcher with the system map for minute to minute operations. Secondly it will serve as an alarm board for the grid. Control Desk: The control desk, which will face the mimic board will have instruments showing the frequency, total Mw generation tie line flows etc. The control desk will have direct telephone facilities with all major grid and generating stations, Computation devices: A digital computer of suitable size shall be provided at the despatching station to make speedy calculations of system conditions including load flows, short circuit levels, economic scheduling etc. Speech communication, teleprinting and telemetering facilities should be provided at regional load despatching station and state load despatching stations as detailed in the previous chapter.

The number of quantities to be telemetered should be restricted to the minimum possible. The following telemeasurements would generally suffice.

i) Total generation of all generating stations (Mw and MVAr).

ii) Mw and MVAr flows of important grid line and inter state/inter-regional lines.

iii) Voltages at important points of the network.

Similarly telesignalling may be confined to the main grid line/ inter-state line circuit breaker positions and tap positions of important transformers.

Recording instruments such as system frequency, total output of generators, flows in the lines, etc. shall also be provided.

For keeping a watch over system frequency, standard frequency crystal controlled generator or a battery operated astronomical clock may be provided at the despatching station. Associated with either of those is a differential clock which measures the difference between the synchronous time (operated by the system frequency) and the standard (astronomical) time.

6.7 State Load Despatching Station.

The state load despatching station will serve as the most important link of the organisation. They will have an over all control of the state power system and will be fully responsible for its optimum and coordinated operation. The state load despatching stations will comprise of two distinct wings i.e. one control wing and other despatch wing. Control Wing: In order to supervise and direct the operations of the load despatching, one load despatcher assisted by one or two operators (depending upon the size of the network) will be required round the clock. The despatcher will be incharge of the system during his shift and willlook after the following works.

1) Control of generation to adhere to the generation schedules closely.

2) Control of frequency: Maintaining system frequency within the limits by suitable changes in generation/loads.

3) Data recording: will collect such technical data which are not telemetered from the various points of the network, receives telephone/teleprinter messages and makes alterations in mimic diagram from time to time.

4) Voltage levels: will maintain voltage levels within the limits through judicious use of static/synchronous condensers, transformer tap changings so that satisfactory voltage levels are available even to the tail-end consumers on distribution feeders. Despatching wing: The despatching wing is further divided into two units. One unit is entrusted with the task of carrying out statistical studies relating to the energy generation and consumption, duration and quantum of peak load and off peak load in the system, contribution of hydro and thermal generation to meet these loads etc. The other unit with programming work will prepare yearly, monthly, weekly and daily generation schedules and to study and analyse the reasons for variations of the actual programme from the scheduled programme. The unit will also prepare schedules for overhauling and maintenance of generating units. The programming unit will also despatch the daily generation

schedule to various power stations one day in advance.

Chief Load Despatcher: He will be in over all incharge of the station, and he must be very familiar with the load despatch techniques. His qualifications and duties are as follows:

Qualifications: i) Power system oriented Engineer with an intimate knowledge of current system despatch and operating techniques. ii) Capable of keeping abreast of developments in the field of power system operation and of assessing advanced operating techniques. iii) Possess a high knowledge of administrative ability.

Duties and Responsibilities:

i) Provide operating guidance and directions to the despatch planning and operating staff.

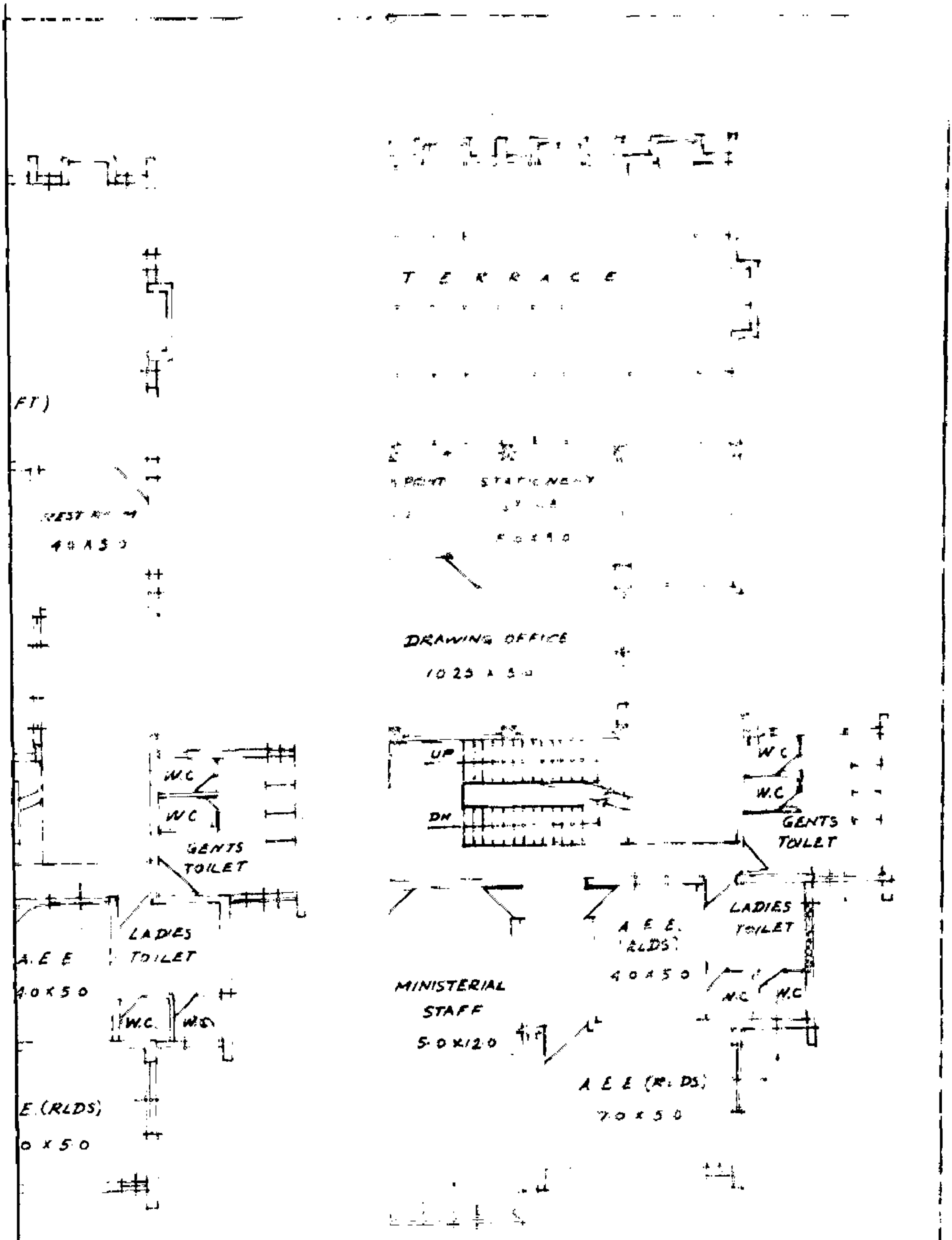
ii) To coordinate energy contracts and agreements with water supply authorities and other fuel suppliers or other personnels who may actually handle the contract negotations.

iii) To determine the emergency procedure policies which include the action to be taken if the system limits are exceeded.

iv) To keep the management and public relations informed, following system disturbances.

v) Liasion Officer with inter-connected utilities and other operational divisions.

6.8 Formation of Regional and State load despatching stations in the Southern region, and the system operation etc. are discussed in Chapter 8. The techniques adopted in some of the advanced countries for reliable and economic operation of power systems are discussed in the next chapter.



OND FLOOR PLAN

OUTHERN REGIONAL
PATCHING STATION
BANGALORE

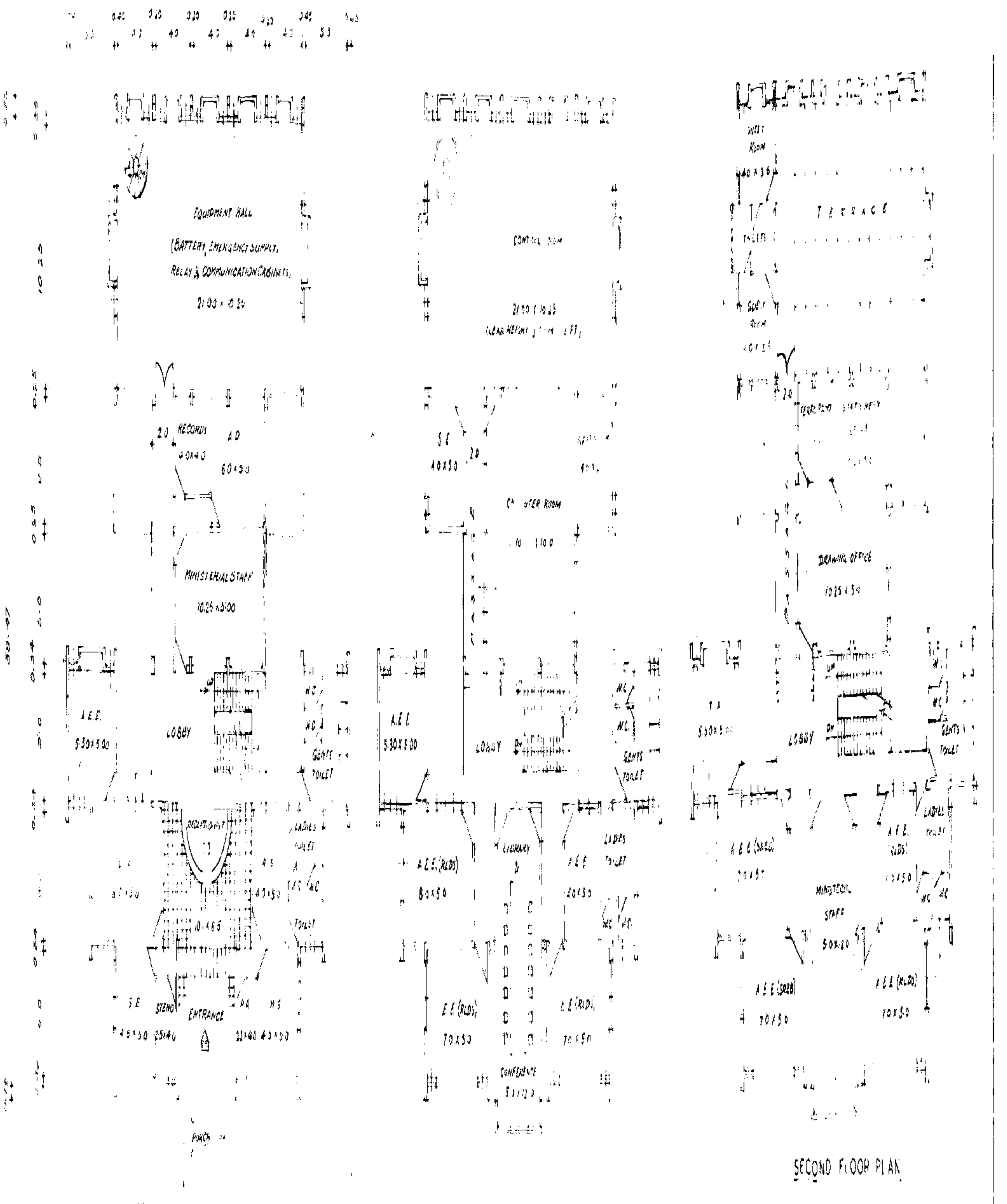


EXHIBIT 6.1

PLAN FOR SOUTHERN REGIONAL LOAD DESPATCHING STATION AT BANGALORE

CHAPTER - 7

LOAD DESPATCHING IN ADVANCED COUNTRIES

7.1 With power systems doubling every 10 years, fuel costs rising rapidly and unit sizes increasing even more rapidly the importance of operating power systems for optimum economy has increased tremendously. The job of first scheduling and then operating the system for optimum economy is not a simple task. Portions of scheduling have become so complex that manual calculations are almost out of the question thus indicating the need for some form computer. Economical and reliable operation of power systems in some of the advanced countries are detailed below.

7.2 U.S.A.

There is a tremendous boost in generation and consumption since 10 years in U.S.A. Generation capability was 222,00 Mw in 1963, 312,000 Mw in 1969 and 401,800 Mw(17) at the end of 1972. Power generation during 1972 was 1767 billion Kwhr.

In 1972, the load growth in U.S.A. outstripped the electrical utilities ability to add to the system capacity. Even though the utilities managed to put a record 34,451 Mw of new generating capacity in service by the end of 1971, the summer peak load was 322,400 Mw (during 1972) and thus providing a reserve margin of 19.6%. Subtracting from this apparent, the 6% or so that power despatchers need for adjusting voltage levels and power flows, it left only 13.6% (spinning reserve) to over come the generation outages.

The total power consumption in U.S.A. will grow 7 to 9 per cent each year at least through the rest of 1970's according to the Electrical Worlds 23rd Annual Electrical Industry forecast.[1] Load growth to an extent of 30,000 Mw or more is ancipated in each year. Hence the electrical utilities will have to put upward of 40,000 Mw of new generation capability on line each year to achieve some what more reserve margin for the load growth.

For operating purposes the national power network in the U.S.A. is divided into six major regional inter-connected groups (as detailed below),[18] each group comprising a number of utilities interconnected with one another.

1. Canadian- United States, Eastern interconnection.
2. P.J.M. interconnection.
3. Inter-connected systems group, Central and South atlantic areas.
4. North-west power pool.
5. Pacific south-west power pool.
5. Texas inter-connection.

The coordination of operation among members within a regional inter-connected group systems varies from an informal day to day barter to a highly sophisticated contractual agreement. The various utilities have generally adopted to tie line load bias control for purposes of system regulation.

Most of the systems were formerly equipped with analogue computers for economy despatch executions. They were followed by digitally computed analogue controls. The present trend is to gain for direct digital computers. on line computers are used particularly in respect of systems having very large thermal generation capacity to obtain optimum economy with higher level of security.

7.3 France

France is the most leading west European country as far power generation and management is concerned. Electricite de France is always abreast with the modern trends and research and developments. In 1967 capacity of thermal and nuclear stations exceeded 15850 Mw and of Hydel installations exceeded 13,710 Mws. The peak load was 19500 Mw[19].

France is connected with almost all the adjoining countries and the exchange of power with them according to the contractual obligations.

Great Britain:	Connected through a 220 Kv.d.c. submarine cable and France supplies about 150 Mw.
Belgium	Interconnection at 225 Kv.
Luxembourg	Interconnection at 225 Kv.
West Germany	Interconnection at 225 Kv.

Switzerland	Interconnection at 225 Kv.
Italy	Interconnection at 225 Kv.
Spain	Interconnection at 225 Kv.

France had adopted integral type load requency regulation both frequency and tie line load deviations are integrated. It is normally called load phase energy regulation. (level control).

For purpose of system operation, the country has been divided into eight regions and a despatching station is located in each region. It addition, there is a national despatching station at Paris entrused with the task of coordinating the activities of the eight regional despatching stations and regulating power exchanges with neighbouring countries and the interconnected system frequency. Thus in so far as the frequency regulation is concerned, it is the National despatching station at Paris which regulates frequency by sending control signals to a number of generating stations spread all over the country through remote control and regional despatching stations had no role to play in the task of frequency regulation.

There are two computers installed in the central load despatching station. One computer is used for the preparation of programme its exploitation and helps in determining the system conditions and economic working. The second computer analyses the values actually being received in every 10 seconds and thus keeps in the surveilliance of the lines or the network on a continuous basis. The entire data received is fed continuously into the computer and which helps to make the decisions rapidly. In case of the latter computer goes out of order the fluctuations are automatically switched into the former computer, cutting off the scientific work in progress.[1]

Under frequency relays are installed extensively and the loads are shed in a preplanned manner to match the frequency within the limits.[1]

7.4 United Kingdom.

There are three principle organisations controlling the power supply in England, Scotland and Wales. Central Electricity Generating Board (CEGB) is the largest organisation having a capacity of 50,065 Mw[20] and the maximum winter peak demand of 37,738 Mw (during 1969). It caters the whole England and Wales, Scotland has two organisations viz. South of Scotland Electricity Board (S.S.E.B.) and North of Scotland Hydro-electricity Board (N.S.H.E.B.)

SSEC and NSHEB are smaller organisations with generating capacities of 5215 Mw and 1816 Mw respectively (1969). Flat tie line transfer of power without any bias for frequency are being maintained between SSEB and NSHEB.

Power transfer between SSEB and CEGB is by mutual agreement through tie line transfer.

CEGB is the largest organisation. It has got 230 power stations with over 1000 generating units and very large transmission network with voltages 132, 275 and

400 Kv. This is the largest system in the world under unified control.

CEGB is divided into 7 areas for operation contorl. Each area has a grid control centre which coordinates its activities with the national control in London. In each grid control (area control), there is load despatching centre which prepares the demand for the area four hours before the time (on the basis of weather, previous requirement, general conditions etc.) and finalise the merit order list (in the order of incremental cost of fuel per Mwhr). Not more than 3% of the occasions, the estimated load would vary by more ± 2.5%.plants selected must meet the area demand plus the scheduled export and the areas share of normal spinning reserve capacity. The average fuel costread from the merit list will be sent to the National cohtrol where these are examined. National despatching station receives schedules for all areas and finalises the optimum transfers keeping in view the security of trunk lines (275 and 400 Kv) when the inter area transfers are communicated to the areas by the National Control, the areas issue instructions in turn to the stations about plant loading two hours in advance. The whole process is repeated every 4 hours.

System frequency is controlled by the grid control station areas and the Scotish Boards applying bias to the instructed transfers. Free governor action 3% of the generating capacity is permitted. Secondary control is provided manually by 7 area controls by frequency bias control[21]. Since the capacity of hydel plants is very much limited and since the thermal units have smaller margin of regulation (economical consideration) a large number of thermal plants share the regulating duty.

Pump storage plant at Pfenstineg having 360 Mw capacity and gas turbines meet the peak load demands. Particularly the former can be brought to full load in less than one minute.

Computers at National despatching station determines the pattern of loading and the transfers at each 400 Kv and 275 Kv sub-stations. It also calculates the power flows with several combination of lines in and out of service, short circuit levels of each sub-station in each combination is also found out.

The regulation of the system frequency by manual control is stated to be quite satisfactory. Under frequency relays are being installed through out the system at supply points to area Boards. The relays are provisionally set to trip 20% of the load at 48.5 cycles/sec and further 20% at 48 cycles/sec.[22]

7.5 U.S.S.R.

The U.S.S.R. power system is divided into six energy systems viz. N.W. and west system 2) European system, 3) Central Asia system 4) Kazakhstan system 5) Caucasion system and 6) Central Siberia system. All these systems are interconnected making it possible to operate the power systems in most economical manner and in particular to take advantage of the time difference between Siberia and the European part of U.S.S.R.

The six systems are divided into 90 regions, each region with a despatching station. There is a central load despatching station at Moscow taking care of 45 nos. regional units of European system. It is incharge of 500 Kv system. Systems below 330 Kv level are operated by regional despatch centres under the over guidance of the central despatching station.

Since the station capacities are very large, frequency regulation does not pose a problem. Each system participates in the regulation of frequency. Two giant size Hydel stations in European system has been found sufficient to cope with the regulating duty.

7.6 The integrated operation of power systems in the southern region, establishment of regional and state load despatching stations, benefits achieved in the region after commencement of integrated operation etc. are discussed in the next chapter.

CHAPTER - 8

KARNATAKA AND SOUTHERN REGIONAL POWER SYSTEMS

8.1 The Southern Regional Electricity Board comprising the States of Karnataka, Andhra Pradesh, Kerala and Tamil Nadu and the union territory of the Pondichery was formed in July 1964. The integrated operation of the Southern Regional grid as well as the Southern regional interim load despatching stations was inaugurated on 14th August 1972, on the eve of the Silver Jubilee of our Independence. These two events in the Southern region have been described as a land mark in the history of power development in the country which paved the way for all India grid. The integrated operation of the four power grids in the region brought a number of technical and economic benefits to all the constituents apart from increasing the reliability of power supply in the region as a whole.

8.2 Functions of the Board.

The functions assigned to the Southern regional Board are as follows:

1. Reviewing the progress of development schemes in the region.
2. Planning and ensuring integrated operation of the power systems in the region in such a manner that any time total amount of electricity generated and transmitted shall give the

maximum possible benefits to the region as a whole.

3. Preparation of a coordinated over-haul and maintenance programme for the generating plants in the region.

4. Determining the generation schedules to be followed by the contituent systems.

5. Determining the quantum of power available for exchange from time to time between the States over and above requirement of each state.

6. Determining a suitable tariff structure to govern exchange of power within the region.

7. Consideration of any other relevant matter for appropriate action taken thereon.

8.3 Power Development in Southern Region.

8.3.1 Installed Capacity.

The installed capacity of the constituent systems and the region as a whole at end of IV Plan (end of 1973-74) are given below.

System	Installed capacity in Mw (end of 1973-74)		
	Hydro	Thermal	Total
Karnataka	966.6	-	966.6
Andhra Pradesh	268.0	402.5	670.5
Kerala	621.5	-	621.5
Tamil Nadu	1224.0	1030.0	2254.0
Region	3080.1	1432.5	4512.6

The details of hydro and thermal stations, number and size of units etc. are shown in the annexure-1. There are 35 Hydro Electric Stations with an installed capacity of 3081.1 Mw and 9 thermal stations including Neyveli, with an installed capacity of 1432.5 Mw, thus bringing the total capacity of 4512.6 Mw. in the region at the end of IV Plan. The demands in the region are increasing rapidly and in fact over striping the available capacity. This is likely to be continued for number of years to come. The integrated operation would therefore enable for utilisation of available generation more economically. A grid map of the Southern Region showing the existing transmission schemes and those under erection during the IV Plan period is shown in the exhibit-1.

The details of Hydro and thermal stations which are under construction and expected to be commissioned during the V Plan are shown in the annexure-2. The total installed capacity in the region will be order of 8972.5 Mw by the end of V Plan.

Exhibit-2 shows the growth of installed generating capacity both Hydro and Thermal in the region. The installed capacity which was 1580 Mw during the year 1963-64 has been increased to 4513 Mw at the end of IV Plan thus an increase of more than 2.8 times for the past 10 years. The exhibits shows the Statewise installed capacity both Hydro and Thermal during the above period.

Both Karnataka and Kerala are rich in hydro power potentials. The hydro power potentials available in Karnataka is estimated to be order of 5500 Mw. So far we have harnessed only about 1000 Mw. Another about 1000 Mw is expected to be harnessed during V Plan and thus remaining a balance of 3500 Mw to be harnessed in subsequent plan periods. Even in Kerala the hydro power potentials harnessed so far is only 621.5 Mw as against an available capacity of 2500 Mw.

More economical benefits will accrue to the southern region if the hydro power potentials available in the above States are explored by the joint venture of all the four states in the region.

8.3.2 Growth of Gross Generation.

Exhibit-4 shows the growth of gross generation both hydro and thermal in the region. The total generation which was 6561 million units during the year 1963-64 has been increased to 17,405 million units at the end of 1973-74, thus an increase of more than 2.6 times for a period of 10 years. The growth of generation on State-wise basis is shown in the exhibit-5.

The energy requirements as assessed by the ninth annual power survey directorate at the end of V Plan and IV Plan periods on Statewise basis are given below

States	Energy requirement assessed in M units.	
	End of V Plan	End of VI Plan.
Karnataka	8760	13,800
Andhra Pradesh	6810	12,000
Kerala	3753	6,050
Tamil Nadu	11865	18,300
Region	31,188	50,150

8.3.3 System Demand.

The peak demand of the constituent power systems and the region as a whole at the end of IV Plan (1973-74) are given below

Karnataka		738 MW.
Andhra Pradesh		643 MW.
Kerala		425 MW.
Tamil Nadu		1331 MW.
Region	a)	3173 (aggregate Demand)
	b)	2890 (coincident demand)

Annexure-3 and exhibit-6 shows the maximum demands of the constituents power systems and the region as a whole from 1957-58. The maximum demand which was 1191 MW during the year 1963-64 has been increased to 3173 at the end of 1973-74, thus an increase of peak demand more than

2.6 times for the last 10 years.

The ancipated peak demands of the constituent systems and the region as a whole at the end of V and VI Plan periods as assessed by the ninth annual power survey committee are given below:

States	Peak Demand in Mw.	
	End of V Plan 1978-79	End of VI Plan 1983-84.
Karnataka	1375	2185
Andhra Pradesh	1270	2210
Kerala	714	1130
Tamil Nadu	2231	3405
Region	5590	8930

Thus tremendous load growth is anticipated during V and VI Plan periods in the region.

8.3.4 Per Capita Consumption:

From the annexure-4 it is seen that the per capita consumption of Karnataka, Andhra Pradesh, Kerala and Tamil Nadu which were 44,21, 40 and 70(units per person per annum) during the year 1962-63 have been increased to 117, 49, 76, and 143 (units per person per annum) respectively at the end of 1972-73. The per capita consumption which is a measure economical development of a country, shows that there is vast development in the region.

8.4 Regional and State Load Despatching Stations.

The state load despatching station at Kalamassery in Kerala State is already functioning. The state load despatching station building at Bangalore for Karnataka is completed and the equipments are under erection. The state load despatching stations for Tamil Nadu and Andhra Pradesh are proposed at Madras and Hyderabad respectively. However sub-load despatching stations have been established in Andhra Pradesh and Tamil Nadu systems which are functioning at Kothagudem and Erode respectively. To coordinate the activities of these four despatching stations and to implement the integrated operation of the regional grid system it was proposed to set up regional load despatching station at Bangalore. The building for regional load despatching station is now under construction at Bangalore. Pending establishment of a permanent regional load despatching station which would take 2 to 3 years time, an interim regional load despatching station is found necessary for smooth and economical operation of the southern regional grid.

The integrated operation of southern regional grid as well as southern regional interim load despatching station was inaugurated on 14th August 1972. The regional grid has been operating successfully and economically. The interim regional load despatching station is functioning at southern regional Electricity Board's office in

Bangalore.

8.5 Inter-State and Inter-regional Lines:

The details of interstate and inter regional lines which are in existance are shown in the annexure-5. These lines are found to more beneficial for reliability and economy exchanges within the states and between regions.

The first inter-connection was established between Karnataka and Tamil Nadu in November 1965. The second was between Kerala and Tamil Nadu systems from Sabarigiri to Madhurai in December 1968. The third was from Munirabad to Hampi interconnecing Karnataka and Andhra Pradesh was established in June 1969 and the forth between Tamil Nadu and Andhra Pradesh between Triruvalam and Chittoor in April 1970.

The first inter-regional line was established between southern and western region from Belgaum (in Karnataka) to Kolhapur (in Maharashtra) in April 1969. The 2nd inter-regional line was established between Southern region and Eastern region systems from Upper Sileru (in Andhra Pradesh) to Balimela (in Orrissa) in August 1973. All the dove interconnections are at 220 Kv level.

The above interconnection lines proved very useful in exchanging of power between states in the region and with the neighbouring regions from time to time.

The inter-state lines which are under construction and expected to be completed during V Plan are as follows:

Name of the Lines.	Distance in Kms.
1. 220 Kv.S.C. Hampi-Gooty Line (Karnataka-Andhra Pradesh)	126
2. 220 Kv.S.C. Ennore-Nellore (Tamil Nadu- Andhra)	176
3. 220 Kv S.C. Pamba- Kayathar (Kerala-Tamil Nadu)	143
4. 220 Kv. S.C. Idikki- Mysore (Kerala- Karnataka)	365

with the above lines it is possible to operate the power systems in the southern region on an inter-connected basis by exchanging the economy power between the states. For integrated operation of the region sufficient inter-state lines are to be established in order to have free power flows in the inter-connected lines. It is suggested that southern regional Electricity Board should take up construction of some more inter-connected lines and the duplication of some of the existing-lines as noted below for satisfactory integrated operation of the region.

1. 220 Kv 2nd circuit between Bangalore- Singarpet
   (Karnataka- Tamil Nadu)
2. 220 Kv. Sc. Line between Shahabad- Hyderabad.
   (Karnataka- Andhra Pradesh)

3. 220 Kv. S.C. line between Idikki- Udumalpet.
(Kerala- Tamil Nadu)

The above lines are shown in exhibit- 1.

8.6 Inter-state and Inter regional power and Energy Exchanges:

The details of power and energy transmitted over the existing inter-state/ inter-regional lines during year 1972-73 and 1973-74 are given below:

Inter-State Lines	Maximum Power Transmitted in Mw		Energy Transmitted in Million Units.	
	1972-73	1973-74	1972-73	1973-74
1. 220 Kv. Bangalore-Singarpet. Karnataka				
to Tamil Nadu	180	150	116	124
Tamil Nadu-Karnataka	192	220	110	176
2. 220 Kv Pamba-Madhurai				
Kerala- Tamil Nadu	200	220	287	314
Tamil Nadu- Kerala	20	-	0.04	-
3. 220 Kv. Munirabad-Hampi				
Karnataka- Andhra	104	83	86	67
Andhra-Karnataka	88	124	33	80
4. 220 Kv. Tiruvalam-Chitoor				
Tamil Nadu- Andhra	72	68	28	30
Andhra- Tamil Nadu	144	29	6	0.3

Inter-Regional Lines

1. 220 Kv. Belgaum- Kolhapur				
Karnataka- Maharashtra	130	115	114	71
Maharashtra- Karnataka	140	160	25	60
2. 110 Kv. D.C. Dandeli- Ponda				
Karnataka- Goa	19	27	91	135
3. 220 Kv. S.C.Balimela- Upper Sileru				
Orissa- Andhra	-	120	-	386

Thus the integrated operation of the region has got many operational advantages and economical benefits. During the Ist year of the integrated operation, 896 million units of energy were transmitted over interstate line representing 5.5% of the total net generation in the southern region. During 1973-74 the corresponding figures were 144.3 million units representing 8.7% of net generation.

It is seen that some of the lines were even over loaded. It is suggested that Souther Regional Board should take up augmentation of inter-state lines in the above routes for reliable operation of power systems.

8.7 Power Cuts in the Region:

Since storage positions in Karnataka, Andhra Pradesh and Tamil Nadu were not satisfactory, demand and energy cuts were introduced in these States while restrictions were imposed from 1.9.1972 in Andhra Pradesh and power cuts were introduced in Karnataka and Tamil Nadu systems with effect from 1.10.1972. Demand and energy cuts are still continuing in those states. However due to the integrated operations it is possible to ~~ex~~ utilise the surplus power available in Kerala in any of the abow States.

8.8 Interim Regional Load Despatching Station:

8.8.1 The interim regional load despatching station (in S.R.E.B's Office) is working round the clock since October 1972. In addition to coordinating the activities of the State load despatching station, the regional load despatching station has been drawing up generation schedules in collaboration with the constituent Boards and the Neyveli Lignite Corporation and also collecting the following data which are required for various studies that are being carried out by southern regional Electricity Boards.

1. Daily generation data at 03.00 hours, 07.00 hours 10.30 hours and 19.00 hours corresponding to the minimum load, morning peak, typical day time demands and evening peaks.

2. Daily operational/ maintenance schedules of generating units in each power station.

3. Power flows over the inter-state/regional links at the hours mentioned above.

4. Half hourly frequency of the grid system.

5. Daily energy generation in each system and energy exchanges between the constituent systems.

6. Half hourly system demands from the constituent systems.

8.8.2 Communication Facilities:

At interim regional load despatching station Bangalore a P and T Telex is provided which facilitate communication with Head quarters of all the constituent state electricity Boards and to the state load despatching centre at Kalamessery and Erode. P.L.C.C. facility is also available for communication with state load despatching station at Erode Kothagudem and Kalamessery.

8.8.3 Mimic Board.

The mimic diagram of all the four power systems in the southern region is represented on a display board. The generation at various power stations in the region, inter-state power flows and voltages at the inter-connecting points at 7.00 hours, 18 hours or 19 hours are displayed on the board. Exhibit-7 shows the mimic diagram of the Southern Regional systems.

A standard clock, a frequency clock and a differential clock and a frequency meter are also installed at regional load despatching station.

8.9 System planning and operation Studies.

The Southern Regional Electricity Board has formed a committee on system study comprising the representatives of the four electricity Boards in the region for carrying out power system planning and operational studies from time to time. This committee formed during December 1971. Since then the committee has been meeting periodically to finalise the proper system data formulate the principles on the basis of which the studies should be carried out and also review the results of the studies.

Operational studies are proposed to be conducted for three representative periods in the year as shown below:

January: period when inflows would have stopped and draw down commenced.

March : Regional peak load condition.

September: Monsoon loading conditions with maximum output from hydro stations (including irrigation controlled stations).

Three typical loading conditions are studied for each period namely morning peak, evening peak and of a typical week day and minimum load on a holiday.

The above studies are beneficial to the region in identifying:

1. Loading of generators- MW and MVAR.

2. The probable morning peak, evening peak and minimum load conditions of the constituent systems and region as a whole.

3. Transmission losses of each system and the region.
4. MW and MVAr flows in major important lines, inter-state lines etc. for different operating conditions.
5. Surplus/ Deficit of power conditions of each state and the extent of power exchanges.
6. Over loading of transmission lines on an outage of one of the lines.
7. Reliability and stability of systems.
8. Voltages at various buses, transformer tappings to be set and capacitor requirements at various buses.

Besides, operational studies the committee has also recently taken up long term planning studies, required to identify the transmission requirements to the region during the fifth 5 year plan-period.

It is suggested that the regional Electricity Board should take up long term planning of systems say 15 to 20 years and to conduct studies to identify transmission and generation requirements in the region. The works contemplated in the long term plan have to be taken up and carried out during annual plan periods. to achieve maximum benefits to the region.

The study committee in addition to the power flow studies, should also carry out short circuit and stability studies for various operating conditions.

8.10 Load Forecasting and Generation Scheduling:

An operating committee comprising the Superintending Engineer/ Executive Engineer/ Divisional Engineers (load despatch) of the constituent Boards, a representative from Neyveli Lignite Corporation and a representative from state regional electricity Board was formed after commencement of integrated operation of the region, to draw up the regional generation schedules, to finalise/review the operating instructions and to discuss the various operational problems connected with the integrated operation of the regional grid system, with a view to take up remedial measures. The committeee is meeting atleast once in every month, to review the generation schedules as per actuals for the previous month and to draw up generation schedules for the following month. Regional generation schedules on half hourly basis round the clock are prepared allocating the generation to be maintained by each and every station in the region. The exhibits- 8&9 shows the load forecasting and generation schedules prepared in the southern regional grid for the month October 1972. The schedules are prepared for a typical working day and for a Sunday/ Holidy in each month. The load demands of the four constituent systems will be worked out based on the load demands recorded on the maximum regional peak demand day of the previous year and suitably projected for the load growth and taking into consideration the possible reduction in demand due to the power cuts imposed in Andhra Pradesh, Karnataka, and Tamil Nadu systems. The following aspects are also considered while preparing schedules.

1. Operation and maintenance schedules of generating units in that month.
2. Generation capability of each constituent system which is based on availability of fuel, cooling water supply to boiler units, operation of plants mainly depending on irrigation controlled etc.
3. Spinning reserve of the region.

For each month the following schedules are drawn.

I. <u>For typical working day.</u>

a) Half hourly demands, exports/imports and total generation to be maintained by each constituent system.

b) Programmed stationwise generation to be maintained by each of the constituent systems to the above demands.

II. <u>For Sunday/Holiday.</u>

a) Half-hourly demands, exports/imports and total generation to be maintained by each of the constituent systems.

b) Programmed stationwise generation to be maintained by each of the constituent systems corresponding to above demands.

The mutual exchanges of power and energy anticipated under different conditions on working day and Sunday/Holiday are indicated in the schedules.

A review of the performance of the regional grid system during January 1975 on actual maximum demand and energy consumptions recorded and those anticipated are given below:

	Antici-pated.	Actual	Percent variation	Reasons for variation.
Karnataka				
Maximum demand (Mw)	800	790	-1.2	Marginal
Energy consumption (M.Units)	422	423	less than 1	Marginal
Andhra Pradesh				
Maximum Demand (Mw)	650	695	+ 7%	Due to increase in Agricultural loads.
Energy consumption (M.Units)	363	374	+3.03	Marginal
Kerala				
Maximum Demand(Mw)	440	424	3.63	Marginal
Energy consumption (M.Units)	215	204	-5	Marginal
Tamil Nadu				
Maximum Demand (Mw)	1175	1162	less than 1%	Marginal
Energy consumption (M.Units)	667	657	1.5%	Marginal

It is suggested that the regional Electricity Board should take up drawal of schedules for weekly and daily basis, one day in advance for deriving maximum benefits. A digital computer is essentially required at the regional despatching station for economic load scheduling and for reliable operation of the power systems in the region.

8.11 System Frequency:

The constituent systems in the region have agreed to operate the systems at a frequency not less than 49.7 Hz and that the importing systems would start shedding loads when the frequency tends to godown below 49.6 Hz. Frequency meters are installed at state load despatching stations and regional load despatching station and these are calibrated with reference to the frequency meter installed at Kalamassery load despatching station.

8.12 Spinning Reserve:

Since Andhra Pradesh and Tamil Nadu systems will be in deficit of both demand and energy no spinning reserve would be maintained in these systems for the present. Generally spinning reserve of 50 MW in Kerala and 89 MW in Karnataka (i.e. capacity of highest machines) are maintained in the region. In view of the fact that Kerala and Karnataka are exporting power to other systems to meet the peak demands, the spinning reserve maintained in these systems will vary to that extent.

8.13 Load Generation Balance:

A study committee consisting of the representatives of the constituent systems, Neyveli lignite corporation and S.R.E.B. deals with the study of power demands and energy requirements vis-a-vis availability of each power system in the region for the year on monthwise basis. The study committee will meet regularly and review the load generation balance schedules prepared for the year and revise the schedules now and then based on system conditions.

In June 1974 the S.R.E.B. brought out a report on load generation balance for the period July 1974 to June 1975 and revised the report in October 1974 based on actual inflows realised at the end of south-west monsoons and the performance of the regional grid during the period from July 1974 to September 1974. The power supply position was again reviewed in January 1975 for the period January to June 1975 at the end of north west monsoons.

An important task of the committee is to identify the anticipated shortages of energy and capacity and suggest to the constituents the percentage reduction that might be required in energy consumption or load demands in their systems with a view to imposing suitable restrictions on power supply.

8.14 Optimisation of Generation:

The present installed capacity of the region is 4732 Mw comprising of 3079.5 Mw of Hydro and 1652.5 Mw.

of thermal. Thus more economical benefits will accrue to the region by optimisation of generation.'

A study committee consisting of representatives of the constituent systems, and state regional electricity Board was formed for examining various aspects of optimisation of generation in the region. The study committee has finalsed the data to be collected in respect of hydro and thermal stations from the constituent systems.

Due to the imposition of power cuts in Tamil Nadu Andhra Pradesh and Karnatka, the optimisation of generation is not practicable for the present. However due the commissioning of number of Hydro and thermal plants in the region by the end of V Plan, the southern region can be operated more economically by optimising generation on regional basis. Further it is necessary to plan for installing despatching computers at state load despatching stations for economical operation of the region.

8.15 Benefits of integrated operation of Southern Regional Power systems:

The maximum demands of the contituent states in the southern region exhibit a marked diversity due to geographical factors. The pattern of monthly maximum demands in the constituent systems during the year 1973-74 is shown in the annexure- 6 and exhibit 10. The monthly diversity factors varied from 1.058 to 1.165 which corresponds to a diversity benefit of 124 to 337 MW. The annual diversity factor was 1.1 and the corresponding benefit was 283 MW. The maximum daily diversity factor was 1.126 which gave a diversity of 287 MW. The maintenance schedule of generating units in each state in the southern region were drawn up by the regional electricity Board in collaboration with the constituent states, keeping in view these diversities. The diversity was also effectively made use in the operation of the southern system by providing spinning reserve, peaking assistance to capacity deficit systems etc. The spinning reserve maintained in Kerala and Karnataka power Systems helped to regulate frequency and meet the deficit on account of sudden loss of generation in the entire grid. This resulted in maintenance of better frequency and minimum amount of shedding in deficit systems.

Integrated operation proved beneficial to the deficit and surplus power systems alike in improving the stability in their generating units and the reliability and quality of power supply. The voltage and frequency conditions in all the power systems as a result of inter-connected operation and sudden loss generation at any power station or sudden increase in load was taken care of without much disturbance to the grid conditions.

It was also noticed that there was a seasonal surplus of power in Andhra pradesh and Tamil Nadu which could not be stored in their own reservoirs as they were spilling. The inter-connection of their power systems with Karnataka power system enabled them in Bank this surplus/spill energy with Karnataka power system at Linganamakki reservoir and use it later when they needed it.

Exchange of power continued to take place from time to time between Maharashtra and southern grid system, particularly Karnataka. Maharashtra system was either in parallel with southern regional grid or having loads at Kolhapur fed radially from Belgaum.

Inter connection of power systems in the southern region enabled Andhra Pradesh and Karnataka to enter into barter arrangement with Tamil Nadu for supply of tyres, chassis etc. in exchange of power.

The integrated operation helped in reducing the demand cut in periods of power shortage as the deficit states of Andhra Pradesh and Tamil Nadu could get peaking assistance from Karnataka and Kerala.

It was possible to undertake tunnel repairs at Sharavathy (from 19th August to 3rd September 1972) which means a loss of almost 450 MW of generation with minimum dislocation of power supply. This was achieved by getting surplus power from Kerala wheeled through Tamil Nadu, stepping up generation at Neyveli by suitably scheduling the lignite supplies, prior banking of energy with Tamil Nadu and suitable staggering of maintenance of generating units in Andhra Pradesh, Kerala and Tamil Nadu.

A better disciplined in system operation, toning up communication facilities in the constituent systems, development of rationalised programming procedures (i.e. inflow computation, load forecasting etc.) and better understanding of the planning, operation and accounting problems have also resulted since integrated operation commenced.

The integrated operation has also brought out an excellent spirit of cooperation among the constituent systems and full confidence in the regional Board.

Besides the above benefits which occured to the state in the day to day operation of their power systems, integrated operation helped the constituent states to tide over a number of emergencies. A few instances are given below:

Date	System giving assitance	System receiving assistance	Quantum in Mw.	Cause of Emergency.
15.8.72	Karnataka	Tamil Nadu	60	Total shutdown at Ennore
23.8.72	Kerala	Tamil Nadu	100	Strike at Neyveli
2.11.72	Karnataka	Andhra	50	failure of one of 60 Mw set at Upper Sileru
7.8.73	Karnataka	Andhra	70-80	Lower generation at Kothagudem.
19.8.73	Tamil Nadu	Karnataka	100	Tunnel inspection at Sharavathy
7.10.73 to 10.10.73	Karnataka	Tamil Nadu	60	Reduction Neyveli generation from 200 to 120 Mw.

9.10.73 to 10.10.73	Kerala	Tamil Nadu	50	Reduction in generation at Neyveli from 200 to 120 Mw.
1.12.73 to 3.12.73	Tamil Nadu	Karnataka	150	Inspection of power channel Sluice gate at Linganamakki.
1.12.73 to 3.12.73	Andhra	Karnataka	50	-do-
14.12.73 to 18.12.73	Karnataka	Tamil Nadu	60	Generation at Mettur Tunnel reduced from 136 to 8 Mw.
15.12.73 to 18.12.73	Kerala	Tamil Nadu	100	-do-

8.16 Karnataka State Load Despatching Station:

8.16.1 The speech communication, telemetering teleprinting and telecontrol facilities proposed to the load despatching station are as follows.

8.16.2 Express Speech communication.

The communication facilities provided from load despatch centre to generating stations and other grid stations are shown in the exhibit 11. Express speech facility is provided between load despatch centre and generating and grid stations as detailed under groups I, II and III by providing independent channel to each group.'

Group I: Load despatch centre- to Shimsha generating station.

Group II: Load despatch centre to Peenya or Mysore, or Shimoga or Bhadra or Jog or Mangalore.

Group III: Load despatch centre to Sharavathy or Hubli or Belgaum or Munirabad receiving station or Munirabad generating station or Shahabd.

The load despatcher can have speech communication with any stations in each of the above groups at a time. The carrier channels for express speech communication facility of one group are independent of the channels in the remaining groups. The load despatcher can have simultaneous speech communication with one station in each of the three groups. Further on express channel any station can contact the load despatch centre one at a time independent of the traffic in the remaining two groups.

The carrier sets provided in the load despatch centre are of Hindustan Brown Boveri make which are suitable for simultaneous transmission of the signals pertaining to express speech communication, teleprinting, protective relays, telemetering and load frequency control. In most of the sections only one carrier channel has been provided for the above signals since the carrier sets provided are of single side band fixed frequency type and of multipurpose type, the telemetering/ teleprinting/ protection signals are super-imposed above the speech band.

In the express calling facility the out stations cannot communicate with each other, only communication with load despatch centre is possible.

8.16.3 Teleprinters:

Under the load despatch scheme ten numbers of teleprinters are proposed to be installed at the following places for transmission of messages through carrier link.

1.	Bangalore	3 Nos.
2.	Munirabad	1 No.
3.	Hubli	1 No.
4.	Sharavathi	1 No.
5.	Jog	1 No.
6.	Shimoga	1 No.
7.	Mangalore	1 No.
8.	Mysore	1 No.

Indigenous Audio-frequency shift transmitters/receivers of Hindustan Brown Boveri make, indigenous teleprinters of M/s Hindustan Teleprinters and one number imported 10 line automatic teleprinter exchange of M/s Olivetti, Italy provides teleprinting facility under the load despatch scheme. The signal of the Audio Frequency shift transmitters/receivers are superimposed above the speech band in the associated carrier sets, so that the use of additional carrier channel for teleprinting is avoided.

6.16.4 Telemetoring:

The measurands proposed to be telemetored from the generating stations are:

i) The integrated generation in Mw.
ii) The integrated Megavars.
iii) The H.T. bus voltages.
iv) 220/110 Kv. line breaker positions.

The measurands that are proposed to be telemetored from main receiving stations are:

i) The H.T. bus voltage
ii) The 220 Kv.line breaker positions
iii) Loading of important interconnecting transformers.
iv) Tap position indications of transformers.
v) Power transmitted over interstate and other important grid lines.

Exhibit- 12 shows the routing of telemetoring channels in Karnataka system. The telemetering employed in Karnataka load despatch scheme is a combination of continuous and digital cycle telemetoring systems. Continuous telemetering channels are used for telemetoring the measurands of inter-state lines (Mw and MVAr flows in line) and for the load frequency control system.

With the digital cyclic telemetering equipment, it is possible to transmit and store values originally existing in analogue form, in a digital form without undue technical delay. In this way a high accuracy is obtained with minimum sensitivity to disturbances. At the sending end various measurands like Kv., Mw, MVAr, are converted to the range of 0 to 5 mA by means of measurand convertors and these measurands are fed in the form 0 to 5 mA, for example cyclically scanned in the equipment, converted to binary form in the analogue-to-digital convertor and finally transmitted on the time division multiplex principle. At the receiving end they are converted back to into a defined current in the digital to analogue converter corresponding to that at the transmitting end with an accuracy of ± 0.5%[24]. The interval between two transmission of a particular measurand is tided over a digital storage circuit so that the value that was transmitted last is always available.

8.16.5 Mimic Diagram Board (L.D. Board)

The main circuit of the system network has been presented on the load despatch board in the form of a mimic diagram to facilitate the load despatcher to know the system conditions from time to time. The mosaic portion of the load despatch board consist of plastic tiles of size 45 mm x 45 mm. The position of these tiles are interchangeable, which makes the mosaic portion flexible for incorporating changes in the system layouts at a later date. Centrax indicating instruments are mounted on the mimic diagram board for indicating the various telemetered quantities viz, Kv, Mw, MVAr etc.

Functional position of the circuit breakers with the help of discrepance switches and also the transfommer tap position indications are shown in the mosaic portion of the Load Despatch Board.

A separate totaliser panel consisting the following meters is provided at the Load Despatch centre.

a) One frequency meter.
b) Three numbers of centrax indicating instruments for integrated Mw generation, integrated MVAr generation and summated Mw exchange with neighbouring systems.
c) Six Nos. Linex recorders for recording the generation of each generating station also for recording the total generated Mw in the system.

8.16.6 Load Frequency Control:

The equipment that is being installed at load despatching station for frequency control is proportional integral controller of type DIRB- Brown Bovari make.

The Brown Bovery type DNRB digital system controller is a proportional-integral-controller whose original correcting condition Y is the sum of a proportional and an integral part according to the following equation for frequency-power control[25].

$$Y = 100 \frac{\Delta P_{\gamma}}{P_R} + Y0 = \frac{100}{P_R} \left[C_p (\Delta P + K \Delta f) + C_i \int (\Delta P + K \Delta f) \, dt \right] + Y0$$

where

Y = Correcting condition after control-operation is finished.

$Y0$ = Correcting condition before control operation was started.

P_{γ} = effective out put of the controlled machine. Mw.

ΔP = Control deviation of the tie line power (difference between actual value and desired value = Mw).

Δf = Control deviation of the system frequency ... HZ

K = System bias of the system controller = Mw/HZ

P_R = Available controlling power .. Mw.

C_p = Proportional constant

C_i = Integral constant ... S^{-1}

$T_i = \frac{C_p}{C_i}$ = Integral time of action.

The integral action time indicates the time last at constant control deviation before the correcting condition has altered under the influence of the integral section of the controller by the same amount as generated by the proportional part alone.

The integral time T_i is used as setting value instead of the proportional constant C_p so that the control equation is of the form

$$Y = 100 \frac{C_i}{P_n} \left[T_i (\Delta P + K \Delta f) + \int (\Delta P + K \Delta f) \, dt \right] + Y_0$$

The equations for pure frequency control or pure power control can be derived from this frequency- power control equation.

The controller is built up on a digital principle and is based on the fact that information is available in the form of ~~mix~~ numerals, in plus series or code words which contain only the two conceptions O and L.

The mathematical manipulations contained within the control equation are carried out by counting and comparing the binary numbers.

At present 2 units, each of 89.1 Mw at Sharavathy generating station are proposed for load frequency control.

8.16.7 Principle of working of Load Frequency Control Equipment.

The measured value of the tie line power is converted into digital form by an analogue to digital converter of very high quality (error not more than 0.125%) at the controller input. From this conversion on the actual value of the tie-line power as well as the system frequency (which does only need multiplication at the input) are processed in the controller entirely in digital form upto the output of the controller where the digital to analogue conversion and the power amplification of the correcting condition (output signal) takes place.

The digital principle applied through out the whole controller assures for instance that even very small frequency (Δ f) and power (Δ P) deviations are integrated very exactly because of the zero point of a digital integrator is not shifted by the influence of temperature, small alternations of resistors, capacitors etc. in the line.

The deviation Δ f between actual and desired value of the frequency is displayed by a numerical indicator that shows the sign and four figures Δ f (for example $\pm$ 0.124 C/s) and is mounted in the control desk. This display can also be switched over to show Δ P.

The calculating cycle of the system controller DRRB lasts only 0.11 second. That means a new value of the correcting condition is produced 9 times in the second. This relative high repetition rate was chosen to be out of range of the rotor oscillations of the generating sets.

8.17 Regional Load Despatching Station.

8.17.1 The speech communication telemetering, teleprinting, telesignalling facilities contemplated at regional load despatching station are as follows.

8.17.2 Telecommunication.

Power line carrier link is proposed for voice communication between regional load despatching station with the four state load despatching stations at Kothagudem, Kalamessery, Bangalore and Erode. The telephone facility between the regional despatching station and the state despatching stations will be of simple push button type providing express link connecting regional load despatching station on one hand and state load despatching station on the other. Selective call facility is proposed at regional load despatching station so as to facilitate the station establishing communication with more than one state load despatching station at a time when required. These would be no communication facility between state load despatching stations.

The distances between the regional load despatching station and the four state load despatching stations as measured on power lines are as follows:

Kothagudem (Andhra Pradesh)	976 Kms.
Kalamessery (Kerala)	873 Kms.
Erode (Tamil Nadu)	336 Km.

Bangalore (Karnataka) situated by the side of Regional Load Despatching Station.

The exhibit-13 shows the transmission line routes between regional load despatching station and the terminal stations of the state load despatching stations.

8.17.3 Teleprinting

Teleprinting facility is proposed between the regional load despatching station and each of the state load despatching station for purpose of converying important operational messages etc, one teleprinter with associated equipments is proposed at the regional load despatching station and one for each of the four state load despatching stations.

8.17.4 Telemetering:

The measurands like Mw, MVAr generation etc. that would be available at the state load despatching station are intended to be picked up and transmitted to the regional load despatching station by telemetering equipments. The details of measurands that are proposed to be telemetered from each state load despatching stations to regional load despatching station are as follows:

1. Total Mw generation of the state.
2. Total Mw generation in each of the generating stations.
3. Mw and MVAr flows of inter regional lines
4. Mw flows of important 220 Kv grid lines
5. System frequency.
7. Telesignalling-circuit breaker indications of inter state lines.

Necessary totalisers and the indicating and recording meters are proposed for summation of Mw readings pertaining to four states.

8.17.5 Telesignalling.

The breaker positions of 220 Kv and 110 Kv inter-state lines are transmitted from state load despatching stations to regional load despatching station.only circuit breaker positions of the lines will be telesignalled.

8.17.6 Other equipments such as mimic diagram board, despatchers desk, standard time clock, frequency time clock and the differential clock are also proposed for Regional Load Despatching Station.

8.18 Andhra Pradesh state Load Despatching Station:

The S.L.D.S. is proposed to be established at Hyderabad. The existing load despatching station at Kothagudem will serve as sub-load despatching station after establishment of state load despatching station at Hyderabad. P.L.C. link is used for speech communication from Kothagudem to all major grid and generating stations. In addition to the above, direct express channel network is also provided from state load despatching station to important generating stations. The following quantities are telemetered from generating and grid stations to state load despatching station.

1. Total Mw and MVAr generation at each power station.
2. Bus voltages of important stations.
3. Mw and MVAr flows of important transmission lines.

4. Total Mw and MVAr flows through inter-connecting transfomers 220 and 132 Kv network.
5. Circuit breaker on and off indication for all breakers of generating units, trunk transmission lines.

Mimic diagram of the system with built in meters to show the various telemetered quantitites and to indicate the functional position of the circuit breakers is provided. A separate system console is there to indicate the total generation, frequency and other quantities necessary for the load frequency control. The load frequency control equipment is still under erection. The equipment is similar to the equipment installed at state load despatching station Karnataka. The following stations are contemplated for load frequency-operation.

Upper Sileru	2 x 60 Mw.
Ramagudem	1 x 62.5 Mw.
Kothagudem	4 x 60 Mw.

8.19 Kerala State Load Despatching Station:

The state load despatching station is situated at Kalamassery (being the important load centre). Power line carrier is used for voice communication from state load despatching stations to all generating stations and major grid stations. page printing type teleprinting facilities are provided from load despatching centre to generating stations. The panel board consist of mimic diagram of the power grid & indicating meters such as Mws

MVArs, voltmeters etc. Mw, MVAr, circuit breaker positions are telemetered from all generating stations and important grid lines.

8.20 Tamil Nadu State Load Despatching Station.

At present Tamil Nadu is having load despatch station at Erode. It is proposed to establish State load despatching station at Madras. The Load Despatching Centre at Erode will serve as sub- load despatching station after establishment of state load despatching station at Madras.

At present information is being telemetered to the load despatching centre from the several generating stations. The quantities that are continuously telemetered are Mw, MVAr, bus voltages etc. There is a totaliser panel which gives the integrated generation in Mws and MVArs. Further on this panel recording charts are also mounted. Mw, MVAr and frequency of the system are continuously recorded.

Teleprinting facility has been provided between Erode and Head Office at Madras.

A large scale frequency meter is mounted prominently at the load despatching centre. Generation is maintained correct to the frequency. Kundah is the frequency control station where at a short notice (within about 3 minutes) enough generation can be picked up to supply the grid.

8.21 Load frequency Control for the Southern Region:

The Southern Regional Electricity Board is procuring load frequency control equipment for control of frequency and load on regional basis. The load frequency control will be affected with the help of regional controller, which will be located at Regional Load Despatching Station, Bangalore. The load frequency control on the regional basis would control the inter-regional tie line flows and the frequency of the regional grid taking into account the flows that may exist in the following inter-regional tie lines, namely

1) 220 Kv S.C. Belgaum- Kolhapur
(Southern region- Western region)
2) 220 Kv S.C. Line-Upper Sileru- Balimela.
(Southern region- Eastern region)
3) 110 Kv D.C. Lines Dandeli- Ponda (in Goa)
(Southern region- Western region)
4. 132 Kv D.C. Line Machkund (Orissa)-
Tennuboddara in Andhra.
(Eastern region- Southern region)

The regional controller will work on the basis of the deviations in the scheduled inter regional tie line flows and the system frequency from which the area requirement would be calculated and control signals obtained.

The generation controller at the four state load despatching stations would work in conjunction with the Regional Controller so that after participation of the state systems has been allocated by the regional controller to four state load despatching stations, the states participation could be distributed by the generation controller to the various plants depending upon their scheduled shares.

The following generating stations in the four constituent state systems are proposed to put under load frequency control.

Andhra Pradesh

Upper Sileru	(Hydro)	2 x 60 Mw.
Kothagudem	(Thermal)	1 x 60 Mw.
Ramagudem	(Thermal)	1 x 62.5 Mw.
Upper Sileru	(Hydro)	4 x 110 Mw.
Kothagudem	(Thermal)	4 x 110 Mw.
Srisailam	(Hydro)	4 x 110 Mw.

Karnataka

Sharavathy	(Hydro)	8 x 89.1 Mw.

Kerala

Sabarigiri	(Hydro)	6 x 50 Mw.
Idikki	(Hydro)	6 x 130 Mw.

Tamil Nadu

Kundah	(Hydro)	5 x 35 Mw.
Ennore	(Thermal)	3 x 110 Mw.
Neyveli	(Thermal)	3 x 100 Mw.

The load frequency controller is suitable for any of the following operations.

1. Flat frequency control.

2. Flat tie line control.

3. Tie line load bias control.

The system controller shall basically summate the interchange power deviations with the frequency deviation multiplied by the power number (or system bias) and set up the total deviation or the regional requirement. This regional reqirement is then be distributed as continuous control signals to the various state load despatching stations and from there to the power stations (units).

The load frequency control equipment proposed to regional load despatching centre is similar to the equipment procured by Karnataka.

8.21 Application of L.F.C. on Regional basis.

It is suggested that load frequency control on a regional basis should be considered by S.R.E.B. only at a later date when all the constituent state despatching stations have come up and number of inter-state ties of adequate capacity have developed so that the regional system can operate as one system with free flowing of power in ties throughout the system, the regional despatching station could directly regulate the frequency. Since the tie lines are not sufficient,it is better to install load frequency control equipment only at state load despatching stations and to operate the system with a bias control on inter-state lines. The working of such an arrangement is enumerated below.

8.22 Load frequency control for Southern Region on area basis.

The exhibit 14 shows the proposed arrangement of L.F.C. system for the Southern region. Each state is considered as an area inter-connected with the neighbouring states or areas. The Southern region comprises of Karnataka, Andhra Pradesh, Kerala and Tamil Nadu systems are inter connected with the following tie lines.

Karnataka- Andhra		220 Kv. S.C. Munirabad- Gooty line.
Karnataka- Kerala		220 Kv. S.C. Mysore - Idikki Line.
Karnataka- Tamil Nadu		220 Kv. S.C. Bangalore Singarpet line.
Andhra- Tamil Nadu	i)	220 Kv. S.C. Tiruvalam- Chittoor Line.
	ii)	220 Kv. S.C. Nellore- Ennore Line.
Kerala-Tamil Nadu	i)	220 Kv. S.C. Pamba-Madhurai line
	ii)	220 Kv. S.C. Pamba- Kayathar line.

The systems can be operated more efficiciently by applying tie line bias control to above tie lines. Karnataka and Andhra Pradesh have already procured L.F.C. equipments for their L.D. centres.

From every tie line T the value of power being transferred will be telemetered to each load despatching stations as shown by the arrowed lines. At despatching stations the algebraic sum of the transfers is calculated. similarly with reference to the standard (50 cycles per second), the deviation from the standard frequency is determined. From the deviation dp from the scheduled value of inter-change and the deviation df from the standard frequency, the regulating quantity dp + kdf is derived in all the four stage systems. Suppose a load comes on Andhra Pradesh system which is importing at that time, where as Karnataka and Tamil Nadu are exporting frequency will go down and the import of Andhra system will instantaneously increase. Telemetering from T_{Ar} and T_{Ak} will give a net increase in import, because the frequency has gone down, so that $dp_A + K_A\,df \neq 0$ and it will give a negative value. The despatching station at Andhra will send orders to its regulating stations to increase its generation until $dp_A + K_A\,df$ becomes zero. For Karnataka system $dp_K + K_K\,df$ will be zero so that the Karnataka system does not require correcting its generation. Similarly for Tamil Nadu also does not require correcting its generation. Thus we see that the tie line load bias control on state basis is best suited for the southern region.

The systems can also be operated on flat frequency control or on flat tie line load control basis.

8.23 Under Frequency conditions:

The frequency regulators, no doubt match the generation with the prevailing load demand. conditions like loss of generation, faults in generating stations busbars etc may cause considerable imbalance resulting in frequency drops (if the spinning reserve and other possibilities are exhaused. Such a situation is highly undesirable, both from the operational and consumer point of view. Hence it is necessary that each operating area plans well for shedding of loads in a methodical way in the event of fall of frequency below a certain level.

Planned load shedding is done to improve the frequency if the drop of frequency is below a requisite level. Generally a standard load shedding schedules is prepared and followed in case of exigencies. Under frequency relays are installed in many systems which are given different settings and are actuated at different values of under frequencies and cut out different lines or tie line loadings to bring the frequency close to the standard value. In the meanwhile every effort will be made to resume the lost generation.

In France under frequency relays are installed extensively and a well planned load shedding is adopted in an attempt to maintain frequency within reasonable limits. Even in England under frequency relays are being installed in all the areas.

In Tamil Nadu system under frequency relays are installed in all the major sub-stations to enable prompt load shedding, when the frequency drops down due to grid disturbances.

Even in Karnataka system solid state under frequency relays are being installed at several sub-stations for load shedding when the frequency drops down to the requisite level.'

The Southern regional grid will be better controlled if the under frequency relays are also installed in Andhra Pradesh and Kerala systems also.'

More benefits such as economy interchange, spinning reserve requirements, reliability etc. will accrue to the region by adopting various load despatch techniques enumerated above systematically to the power systems in the region.

ANNEXURE - 1

INSTALLED CAPACITY IN THE SOUTHERN REGION AS ON 31.3.1974

(END OF IV PLAN)

KARNATAKA

Hydro	No. and capacity of sets in MW.	Total capacity in MW.
1. Bhadra	1x2 + 2x12 + 1x7.2	33.2
2. Jog	4 x 12 + 4x18	120.0
3. Munirabad	3 x 9	27.0
4. Sharavathi	8 x 89.1	712.8
5. Shivasamudram	6 x 3 + 4 x 6	42.0
6. Shimsha	2 x 8.6	17.2
7. T.B.Dam(share from Hampi & Tungabadra)	(4x9 + 4x9) (20%)	-14.4
	Grand Total	966.6

ANDHRA PRADESH

Hydro		
1. Machkund	3x21 + 3x17 (70%)	80.0
2. Upper Sileru	2x 60	120.0
3. Nizamsagar	2 x 5	10.0
4. T.B.Dam(Hampi and Tungabadra)	(4 x 9 + 4x9) 80%	- 58.0
	Total Hydro	- 268.0 --

Thermal		
1. Kothagudem	4 x 60	240.0
2. Ramagundam 'A'	3 x 12.5	37.5
3. Ramagundam 'B'	1 x 62.5	62.5
4. Nellore	1 x 30	30.0
5. Hussain Sagar	1 x 7.5 + 1 x 5	12.5
6. Gas Turbines	1 x 20	20.0
	Total Thermal	402.5

	Grand Total	670.5

KERALA

Hydro

1. Kuttiadi	3 x 25	75.0
2. Sholayar	3 x 18	54.0
3. Poringalkuthu	4 x 8	32.0
4. Pallivasal	3 x5 + 3x7.5	37.5
5. Sengulam	4 x 12	48.0
6. Panniar	3 x 15	45.0
7. Nariamangalam	3 x 15	45.0
8. Sabarigiri	6 x 50	300.00
	Total	621.5

TAMIL NADU

Hydro

1. Pykara	3x7.25 + 2x10 + 2x14	70.0
2. Moyar	3 x 12	36.0
3. Kundah 1 to 5	3x20+ 5x35+2x60 + 1x50 + 1x20	425.0
4. Mettur Tunnel	4x50	200.0
5. Mettur Dam	4x 10	40.0
6. Parambikulam Aliyar Aholayar 1 & 2 Sarkarpathy	1x60 + 2x35 + 1x25 + 1x30	185.0
7. Papanasam	4x7	28.0
8. Periyar	4 x 35	140.0
9. Kodayar 1 & 2	1x60 + 1x40	100.00
	Total Hydro	1224.0

Thermal

1. Basin Bridge	2x15 + 2x30	90
2. Ennore	2x60 + 2x110	340
3. Neyveli	6x50 + 3x100	600
	Total Thermal	1030
	Grand Total	2254

Southern Region

Total Hydro	3081.1
Total Thermal	1432.5
Grand total for the region	4512.6

ANNEXURE - 2

GENERATION SCHEMES UNDER CONSTRUCTION/PROPOSED YIELDING BENEFITS DURING THE V PLAN PERIOD IN SOUTHERN REGION.

KARNATAKA

Hydro	No. & Capacity of sets.	Total Capacity on Mw.
1. Sharavathi	2x89.1	178.0
2. Linganamakki	2x 27.5	55.0
3. Kalinadhi	5x 135 + 2x50	775.0
	Total Hydro	1008.0

ANDHRA PRADESH

Hydro		
1. Srisailam	3x110	330
2. Lower Sileru	4 x 100	400
3. Upper Sileru Extension	2 x 60	120
	Total Hydro	850

Thermal		
1. Kothagudem Stage III	2x110	220
2. Kothagudem Stage IV	2x110	220
3. Vijaywada	1x 200	200
	Total Thermal	640
	Total Hydro & Thermal	1490

KERALA

Hydro

1. Idikki Stage I	3x130	390
2. Idikki Stage II	3x130	390
3. Silent Valley	2x60	120
4. Idamalayar	1x37.5	37.5
	Total Hydro	937.5

TAMIL NADU

Hydro

1. Kundah stage IV	1x60 + 1x50	110
2. Suruliar	1 x 35	35
3. Kadamparai pumped storage scheme	1 x 100	100
	Total Hydro	245

Thermal

1. Ennore Extension	1x110	110
2. Tuticorin Thermal	1x 200	200
	Total Thermal	310
	Total Hydro & Thermal	555
Nuclear Kalpakkam	2x235	470

Southern Region

Total Hydro	3040.5
Total Thermal (including Nuclear)	1420.0
Total Hydro & Thermal	4460.5

ANNEXURE -3

GROWTH OF MAXIMUM DEMANDS

(From 1957-58 to 1973- 74)

(All figures in MW.

Year	Andhra Pradesh	Karnataka	Kerala	Tamil Nadu	Total for the region Aggregate	Simultaneous
1957-58	-	150	82	226	458	
1958-59	-	157	88	274	519	
1959-60	146	169	93	335	743	
1960-61	190	176	107	381	854	
1961-62	191	184	122	460	957	
1962-63	191	182	132	532	1037	
1963-64	204	213	144	630	1191	
1964-65	245	260	156	652	1313	
1965-66	258	302	174	717	1451	
1966-67	290	344	212	857	1703	
1967-68	336	387	240	964	1927	1759
1968-69	441	452	353	997	2243	2056
1969-70	524	541	401	1116	2582	2334
1970-71	562	628	440	1155	2785	2500
1971-72	639	695	465	1326	3125	2764
1972-73	608	741	472	1190	3011	2768
1973-74	634	783	425	1331	3173	2890

NOTE: Power cuts have been imposed in Andhra Pradesh, Karnataka and Tamil Nadu during the years 1972-73 and 1973-74.

ANNEXURE - 4

PER CAPITA CONSUMPTION IN THE SOUTHERN REGION AND ALL INDIA

(From 1957-58 to 1972-73)

(All figures in kWh/person/annum)

Year	Andhra Pradesh	Karnataka	Kerala	Tamil Nadu	All India
1957-58	-	23	-	27	28
1958-59	12	37	-	37	31
1959-60	16	38	-	47	35
1960-61	17	44	30	60	38
1961-62	21	45	37	62	44
1962-63	21	44	40	70	48
1963-64	22	50	36	75	54
1964-65	23	52	37	83	57
1965-66	27	55	40	93	61
1966-67	25	58	47	98	66
1967-68	33	62	61	105	72
1968-69	40	70	66	116	78
1969-70	45	62	69	120	84
1970-71	50	104	72	123	90
1971-72	53	117	72	133	94
1972-73	49	117	76	143	97(1)

(1) Provisional

ANNEXURE 5

DETAILS OF INTER-STATE/REGIONAL LINES

Sl. No.	Voltage & No. of Circuits.	Inter-State/ Regional Lines.	Date of Commissioning.	Total distance in Km.
Inter-State				
1.	220kV S/C	Bangalore-Singarapet (Mysore)-(Tamil Nadu)	24.11.65	162.00
2.	220 kV S/C	Madurai-Pamba (Tamil Nadu)-(Kerala)	Dec.1968	161.00
3.	220 kV S/C	Munirabad- Hampi (Inter-State link between Mysore & Andhra Pradesh)	26.3.70	26.00
4.	220 kV S/C	Tiruvalam-Chittor (T.Nadu)-(A.Pradesh)	10.1.71	27.00
5.	110 kV S/C	Mangalore-Kasargode (Mysore)-(Kerala)	13.1.66	39.00
6.	66 kV S/C	Vellore-Chittoor (T.Nadu)-(A. Pradesh)	15.2.66	39.00
7.	66 kV S/C	Gowribidanur-Hindupur (Mysore)-(A.Pradesh)	15.2.66	26.00
Inter-Regional				
8.	220 kV S/C (on D/C towers)	Belgaum-Kolhapur (Mysore)-(Maharashtra)	22.4.69	95.00
9.	110 kV D/C	Dandeli-Ponda (Mysore)-(Goa)	6.11.66	85.00
10.	220 kV S/C	Upper Sileru-Balimela (A.Pradesh- Orissa)	15.8.73	25.00

(Note: Mysore is now called as Karnataka).

ANNEXURE - 6

MONTHLY LOAD PATTERNS AND DIVERSITY FACTORS (1973-74)

Month	Regional Peak		Monthly Diversity factors.	Available margin due to diversity in Mw.
	Aggregate	Coincident.		
April 1973	2229	2105	1.058	124
May	2284	2126	1.074	158
June	2587	2269	1.140	318
July	2983	2646	1.165	337
August	3039	2775	1.095	264
September	3064	2884	1.062	180
October	2968	2773	1.070	195
November	3040	2806	1.086	244
December	3055	2835	1.077	220
January 1974	3132	2890	1.084	242
February	3125	2874	1.093	251
March	3069	2859	1.073	210

SOUTHERN REGION

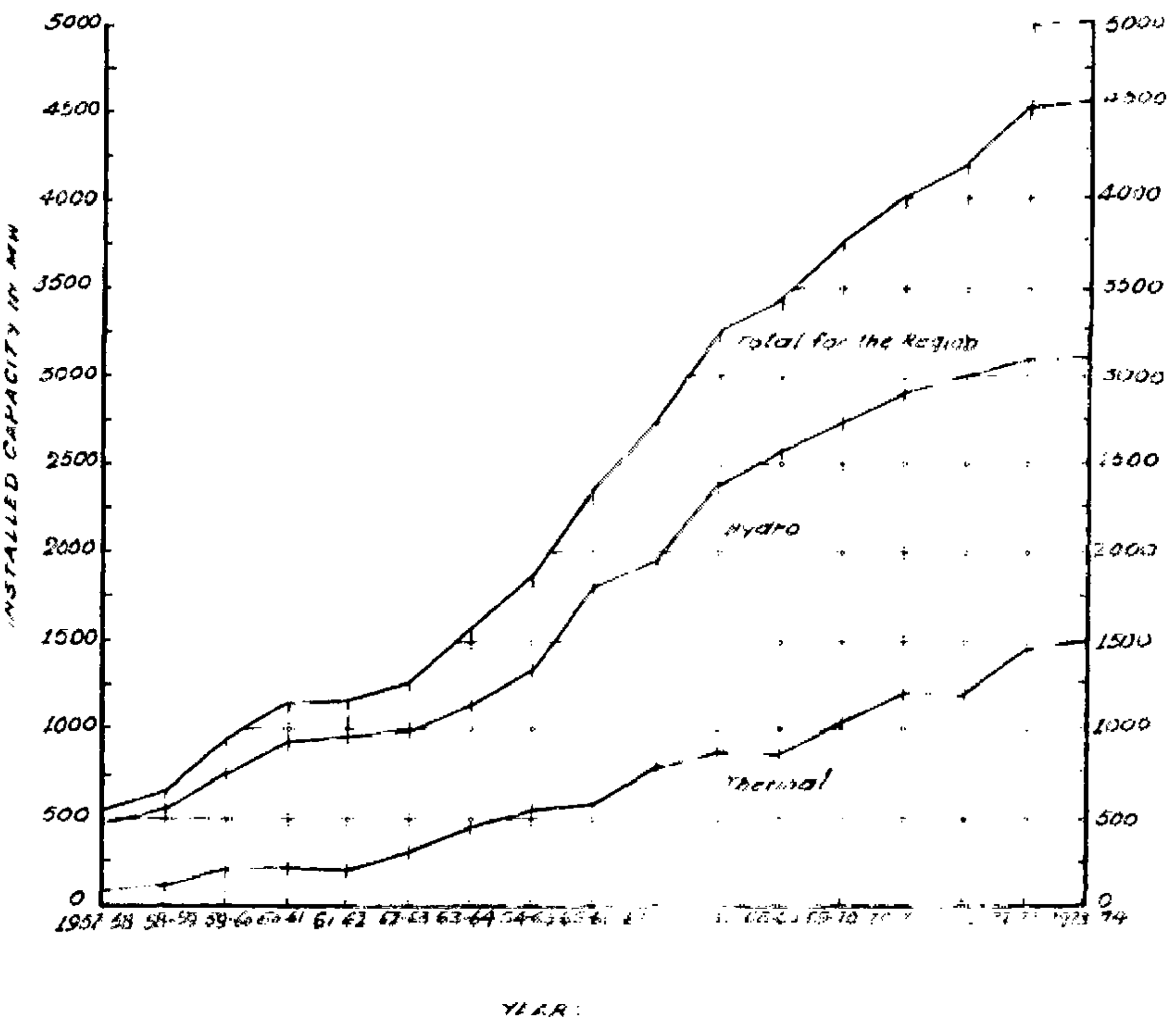


EXHIBIT 2 . GROWTH OF INSTA... GENERAT... ...

...REGION 1957... TO 1973-74

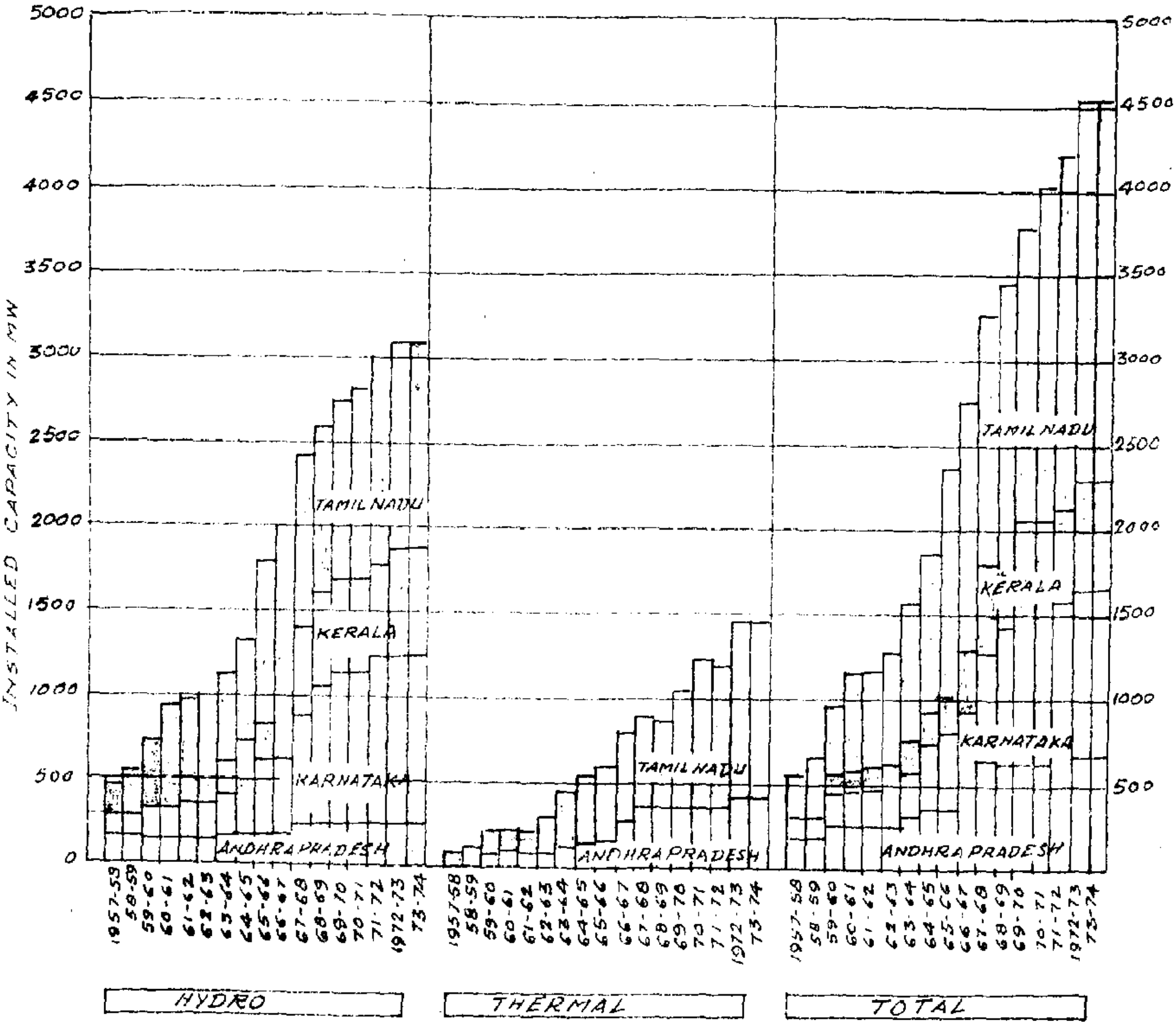


EXHIBIT-3. INSTALLED GENERATING CAPACITY STATEWISE
(FROM 1957-58 TO 1973-74)

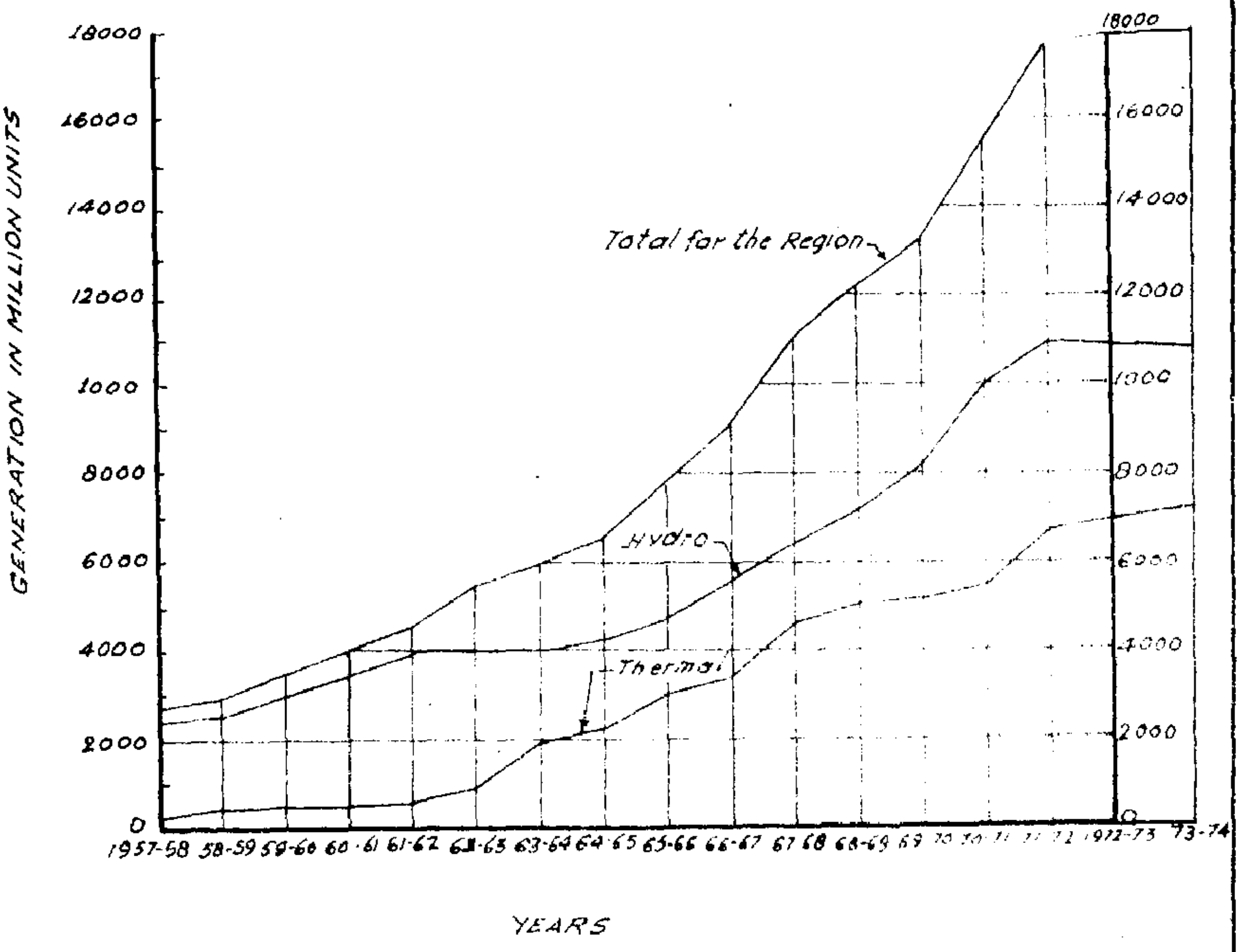
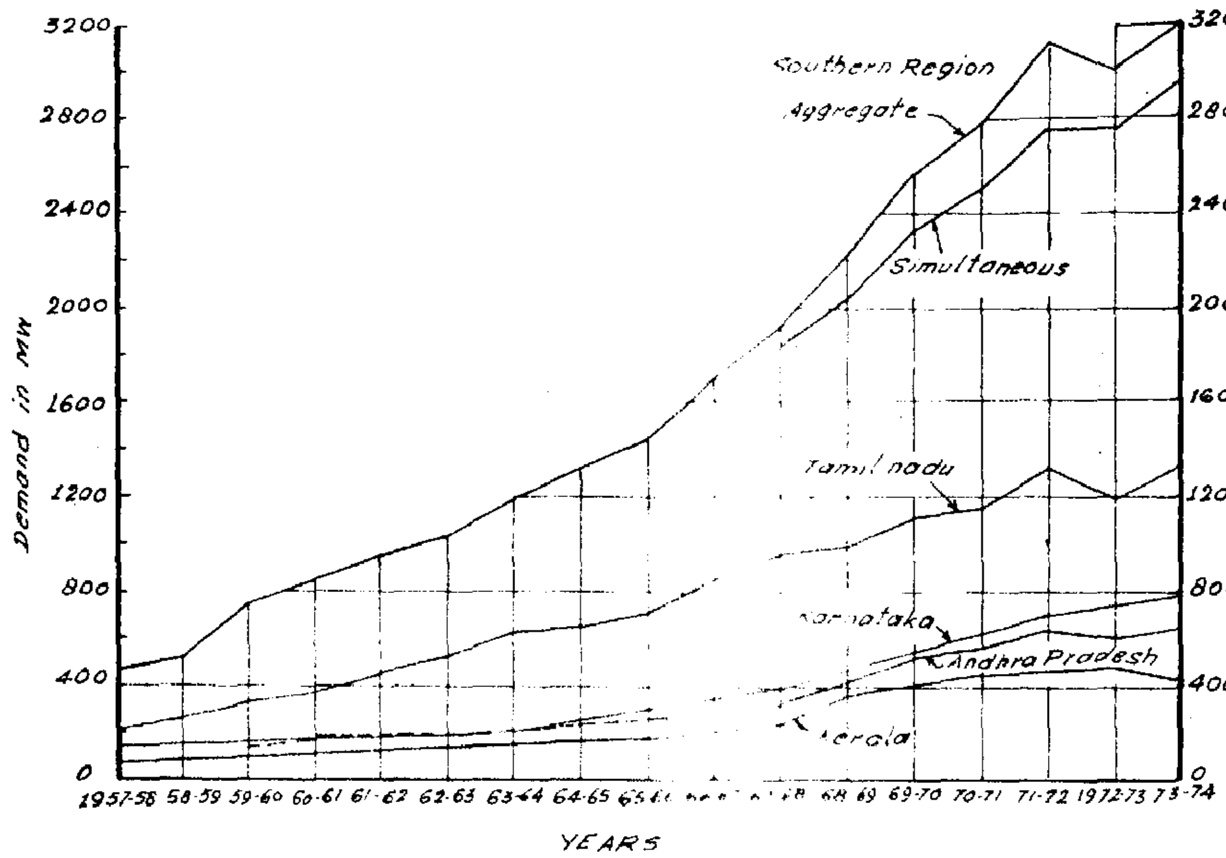


EXHIBIT- 4 GROSS GENERATION

(FROM 1957-58 TO 1973-74)



NOTE:- Power cuts had been imposed [illegible] imposed in Andh Pradesh, Karnataka and Tamil Nadu During the Year 1972-73 & 73-74

EXHIBIT -6. GROWTH OF MAXIMUM DEMANDS (FROM 1957-58 TO 1973-74)

SOUTHERN REGION

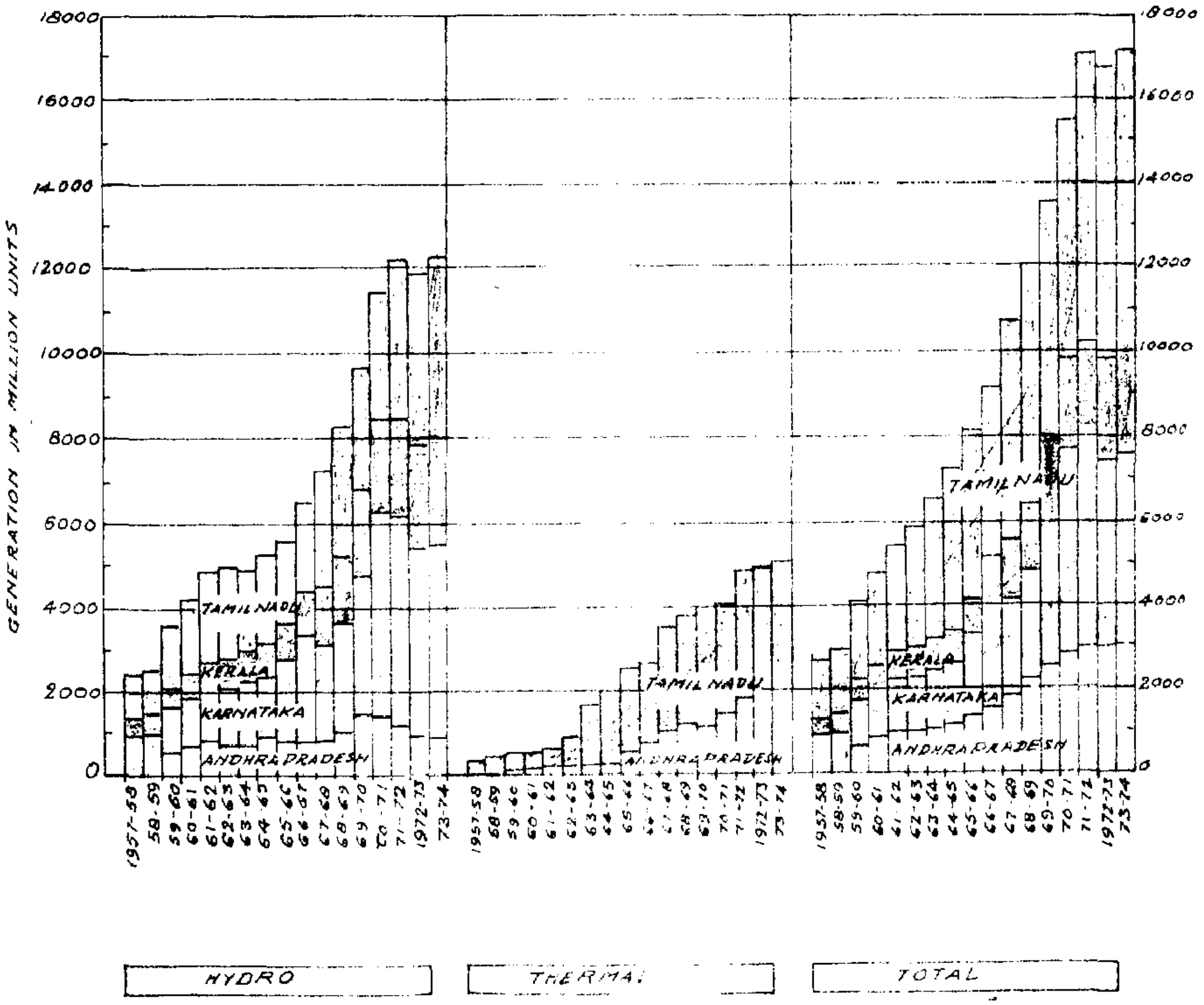


EXHIBIT-5 GROSS GENERATION STATEWISE (FROM 1957-58 TO 1973-74)

SOUTHERN REGIONAL GRID SYSTEM

HALF HOURLY ANTICIPATED LOAD DEMANDS, EXPORT / IMPORT AND GENERATION TO BE MAINTAINED IN THE CONSTITUENT SYSTEMS ON A TYPICAL WORKING DAY IN OCTOBER 1972

ANY DAYS BETWEEN 1-10-72 AND 30-10-72

TIME	A P S E B					K S E B				K E B						T N E B					
	ANTICIPATED LOAD DEMAND	EXPORT(+) OR IMPORT (-)		GENERATION TO BE MAINTAINED	SPINNING RESERVE	ANTICIPATED LOAD DEMAND	EXPORT(+) TO TNEB	GENERATION TO BE MAINTAINED	SPINNING RESERVE	ANTICIPATED LOAD DEMAND (INCLUDES EXPO EXPORT TO GOA)	EXPORT (+) OR IMPORT (-)			GENERATION TO BE MAINTAINED	SPINNING RESERVE	ANTICIPATED (INCLUDES NEY-VELI LOCAL) LOAD	EXPORT (+) OR IMPORT (-)			GENERATION TO BE MAINTAINED	SPINNING RESERVE
		KEB	TNEB								APSEB	TNEB	MAHRASTRA				APSEB	KSEB	KEB		
0.00	320	+20		340		260		260	47	420	-20	-43		353	89	700			+43	743	
0.30	310	+20		330		240		240	67	420	-20	-43		337	89	710			+43	743	
1.00	310	+20		330		230		230	55	425	-20	-53		352	89	690			+53	743	
1.30	310	+20		330		230		230	65	425	-20	-58		347	89	685			+58	743	
2.00	310	+20		330		230		230	65	385	-20	-58		307	89	685			+58	743	
[illegible]	310	+20		330		230		230	65	385	-20	-58		307	89	675			+58	733	
3.00	310	+20		330		230		230	65	445	-20	-58		367	89	665			+58	723	
[illegible]	310	+20		[illegible]		230		230	65	445	-20	-58		367	89	675			+58	733	
4.00	[illegible]	+20		335		230		230	55	465	-20	-58		387	89	700			+56	756	
18.00	[illegible]	[illegible]		503		280		280	35	635	+20	+50		705	89	150(1014)			-50	964	
18.30	540	20		520		345		345	72	715	+20	+50		755	8	1270(1014)			-50	964	
19.00	540	20		520		365		365	52	665	+20	+50		735	68	1120(1014)			-50	964	
19.30	540	20		[illegible]		350		387	87	665	+20	+55		740	63	1065(10.9)			-55	964	
20.00	540(483)	+20		463		370		370	[illegible]	645	+20			665	89	930				930	
20.30	530(463)	+20		443		365		365	90	6.5	+20			635	89	890				890	
21.00	500(407)			407		350		350	55	575				575	89	660				860	
21.30	470(407)			407		320		320	57	535				535	89	820				820	
22.00	440(407)			407		300		300	57	495				495	89	805				805	
22.30	407			407		280		280	77	435				435	69	750				750	
23.00	360			360		270		270	87	445		43		402	89	750			+43	793	
23.30	340			340		265		265	47	435		43		392	89	750			+43	793	
ENERGY IN MU		+0110									0110	02865							-02865		
		-0110									0110	02865	0225						+02865		

Note:-

EXHIBIT 8

i *Load demands include Consumption in power station Auxiliaries and losses in Transmission and distribution systems.*

ii *Figures in Brackets indicate the Restricted demands to be maintained.*

iii *Programmed stationwise generation is given in Exhibit-9 Corresponding to the above Conditions.*

All Figures in MW

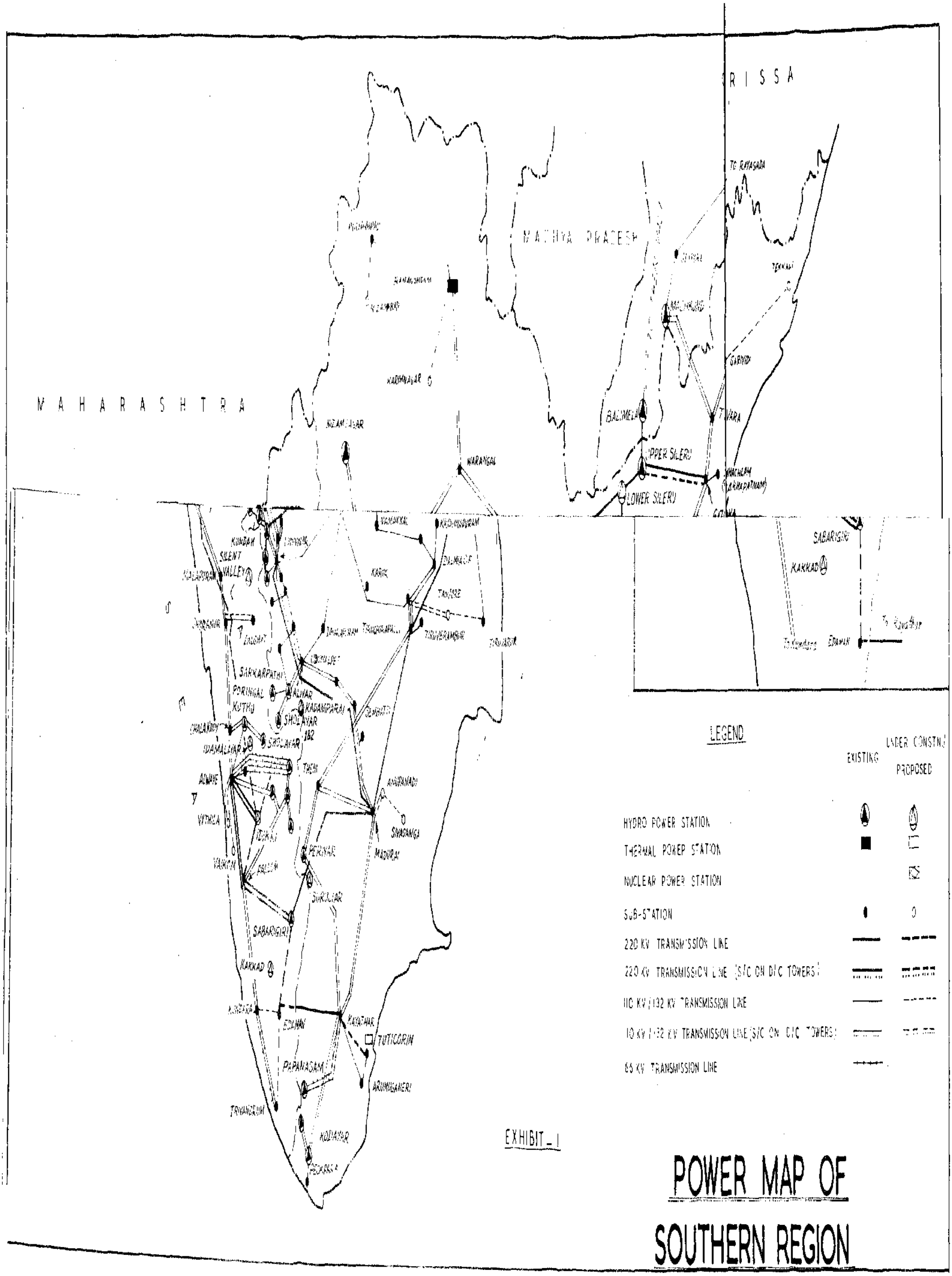


EXHIBIT - I

POWER MAP OF SOUTHERN REGION

SOUTHERN REGIONAL GRID SYSTEM

PROGRAMMED HALF HOURLY STATIONWISE GENERATION IN THE CONSTITUENT SYSTEMS

ON A TYPICAL WORKING DAY IN OCTOBER 1972

(ANY DAYS BETWEEN 1-10-72 AND 31-10-72)

A P S E B

TIME	Total generation to be maintained	Machkund	T.B. Dam	Upper Sileru	Kothagudem	Ramagundam Dam 'A'	Ramagundam Dam 'B'	Nellore	Nagarjuna Sagar
0:00	340	23	42	–	155	15	55	30	–
0:30	[illegible]	23	42	–	[illegible]	15	55	30	–
1:00	330	23	42	–	65	15	55	30	–
1:30	330	23	42	–	155	15	55	30	–
2:00	330	23	42	–	65	15	55	30	–
2:30	330	23	45	–	65	15	55	30	–
3:00	330	23	42	–	65	15	55	30	–
17:00	463	30	48	50	155	20	55	30	5
17:30	443	30	49	40	155	20	55	30	5
18:00	503	30	48	100	65	20	55	30	5
18:30	520	30	25	120	65	20	55	30	5
19:00	527	30	25	20	55	20	55	30	5
19:30	520	30	45	120	65	20	55	30	5
20:00	463	30	48	60	55	20	55	30	5
20:30	443	30	48	40	65	20	55	30	5
21:00	400	30	42	20	165	5	55	30	–
21:30	400	30	42	20	165	15	55	30	–
22:00	400	30	42	20	65	15	55	30	–
22:30	400	30	42	20	165	15	55	30	–
23:00	390	23	42	–	55	15	55	30	–
23:30	340	23	42	–	55	5	55	30	–

K S E B

TIME	Total generation to be maintained	Poringalkuthu	Sholayar	Pallivasal	Neriamangalam	Sengulam	Panniar	Sabarigiri	Kuttiadi
0:00	260	32	10	13	45	12	–	[illegible]	25
0:30	240	32	10	13	45	[illegible]	–	[illegible]	25
1:00	250	32	10	13	45	8	–	107	25
1:30	250	32	10	13	45	8	–	107	25
2:00	230	32	10	13	45	5	–	97	25
2:30	230	32	10	13	45	5	–	97	25
3:00	230	32	10	13	45	8	–	107	25
17:00	260	32	18	13	45	[illegible]	8	25	25
17:30	280	32	19	13	45	12	20	125	25
18:00	280	32	20	13	45	12	20	[illegible]	25
18:30	345	32	20	13	45	5	20	175	25
19:00	355	32	20	13	45	15	20	195	25
19:30	380	32	20	13	45	15	20	210	25
20:00	370	32	20	13	45	15	20	200	25
20:30	365	32	20	13	45	12	20	198	25
21:00	350	32	20	13	45	12	20	183	25
21:30	320	32	10	13	45	12	–	[illegible]	25
22:00	300	32	10	13	45	12	–	163	25
22:30	280	32	10	13	45	2	–	133	25
23:00	270	32	10	13	45	2	–	133	25
23:30	265	32	10	13	45	12	–	123	25

K E B

TIME	Total generation to be maintained	Sharavathi	Jog	Bhadra	Shimsha	Shivasamudra	Munirabad	T.B. Dam	Import from Maharashtra
0:00	357	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
0:30	357	[illegible]	10	6	5	[illegible]	[illegible]	5	
1:00	352	263	10	6	5	16	9	[illegible]	
1:30	347	275	10	6	[illegible]	10	[illegible]	[illegible]	
2:00	307	239	10	6	6	[illegible]	[illegible]		
2:30	[illegible]	239	10	6	6	9	13	5	
3:00	357	259	10	6	6	8	[illegible]	5	
17:00	615	533	10	6	15	25	[illegible]	11	
17:30	665	563	10	6	[illegible]	25	9	11	
18:00	705	513	10	6	16	30	15	11	
18:30	765	593	10	6	16	30	19	11	
19:00	735	644	10	5	16	29	19	11	
19:30	740	644	10	6	16	23	19	9	
20:00	655	563	10	6	16	23	5	9	
20:30	635	552	10	6	16	23	19	9	
21:00	575	492	10	6	16	23	19	9	
21:30	535	452	10	6	16	23	19	5	
22:00	495	421	10	6	5	23	15	9	
22:30	435	364	10	6	6	21	15	5	
23:00	402	330	10	6	6	22	19	9	
23:30	392	320	10	6	6	22	19	5	

T N E B

TIME	Total generation to be maintained	Pykara	Moyar	Kundah 1	Kundah 2	Kundah 3	Kundah 4	Kundah 5	Mettur Dam	Mettur Tunnel	Papanasam	Periyar	Sarkarpathy	Aliyar	Sholayar	Basin Bridge	Ennore	Neyveli	TIME
0:00	[illegible]	[illegible]	[illegible]	[illegible]	150	60	–	20	–	–	16	60	22	20		35	45	200	0:00
0:30	[illegible]	[illegible]	5	60	150	[illegible]	–	20	–	–	16	60			–	35	45	200	0:30
1:00	343	40	5	60	150	60	–	20	–	–	16	[illegible]			–	35	45	200	1:00
1:30	343	40	5	60	150	60	–	20	–	–	16	60	22	20	–	35	45	200	1:30
2:00	303	40	5	60	150	60	–	20	–		[illegible]	60	22	20		35	[illegible]	[illegible]	2:00
2:30	[illegible]	40	[illegible]	[illegible]	[illegible]	[illegible]		20	–	–	16	60	22	20	–	35	45	200	2:30
3:00	[illegible]	40	5	60	[illegible]	60	–	20	–	–	16	60	22	20	–	35	45	200	3:00
17:00	634	70	30	60	165	[illegible]	[illegible]	[illegible]	–		[illegible]	60	22	60	20	35	[illegible]	200	17:00
17:30	[illegible]	70	[illegible]	[illegible]	[illegible]	[illegible]	45	20				60	22	60	20	35	45	200	17:30
18:00	634	70	30	60	[illegible]	[illegible]	45	20	–	–	[illegible]	60	22	60	20	35	45	200	18:00
18:30	664	70	30	60	175	120	45	20	–	–	16	60	22	60	20	35	45	200	18:30
19:00	634	70	30	60	175	120	45	20	–	–	16	60	22	60	20	35	45	200	19:00
19:30	664	70	35	60	175	120	45	20	–	–	16	60	22	60	20	35	45	200	19:30
20:00	630	70	30	60	72	120	45	20	–	–	16	60	22	35	–	35	45	200	20:00
20:30	690	70	30	60	172	120	–	20	–	–	16	60	22	35	–	35	45	200	20:30
21:00	850	70	20	60	172	120	–	20	–	–	16	60	22	20	–	35	45	200	21:00
21:30	820	50	5	60	172	100	–	20	–	–	16	60	22	20	–	35	45	200	21:30
22:00	805	60	5	60	152	95	–	20	–	–	16	60	22	20	–	35	45	200	22:00
22:30	750	60	5	60	132	70	–	20	–	–	16	60	22	20	–	35	45	200	22:30
23:00	793	50	5	60	160	90	–	20	–	–	16	60	22	20	–	35	45	200	23:00
23:30	793	50	5	60	160	90	–	20	–	–	16	60	22	20	–	35	45	200	23:30

ALL FIGURES IN MW   EXHIBIT-9   DATE 30-6-72

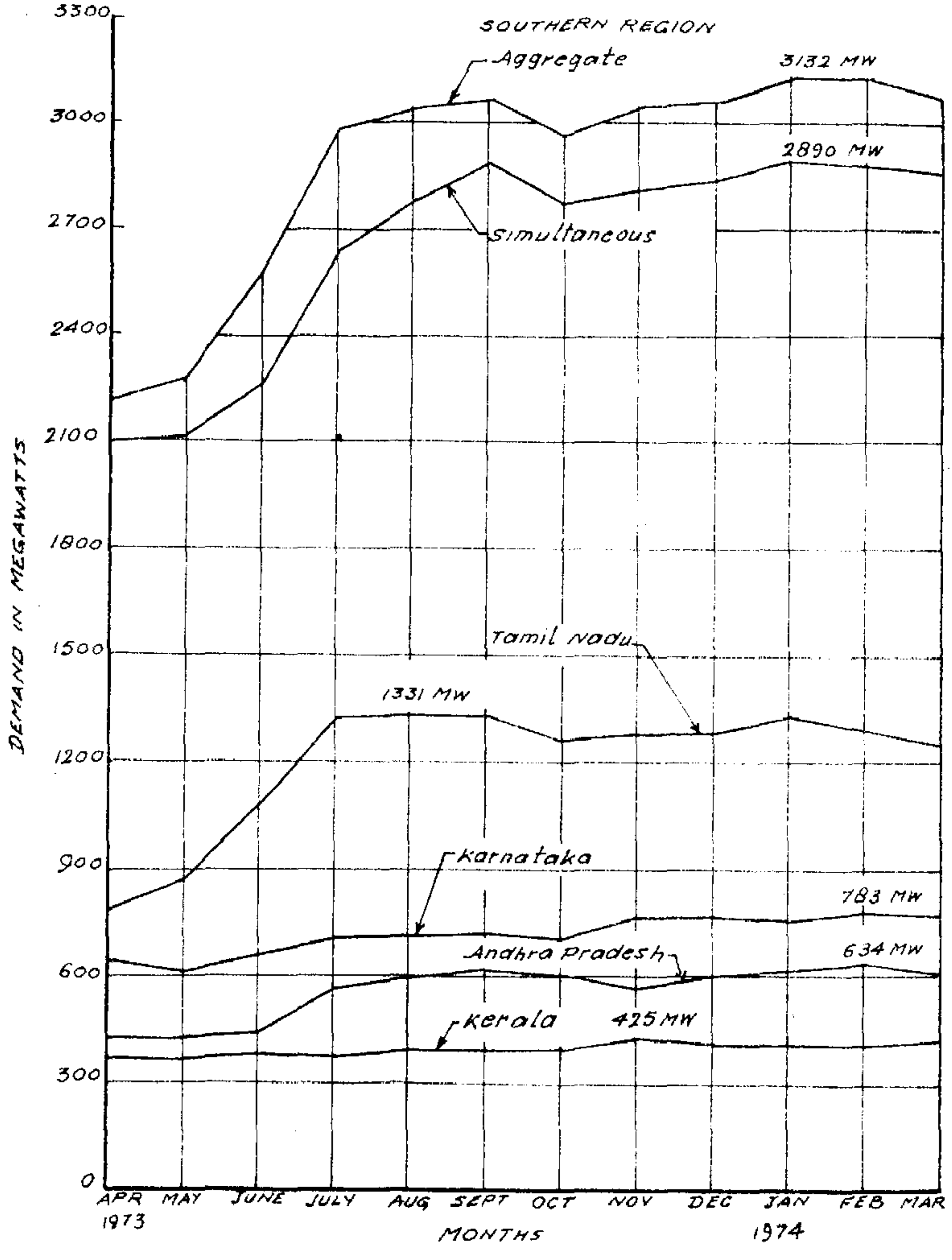
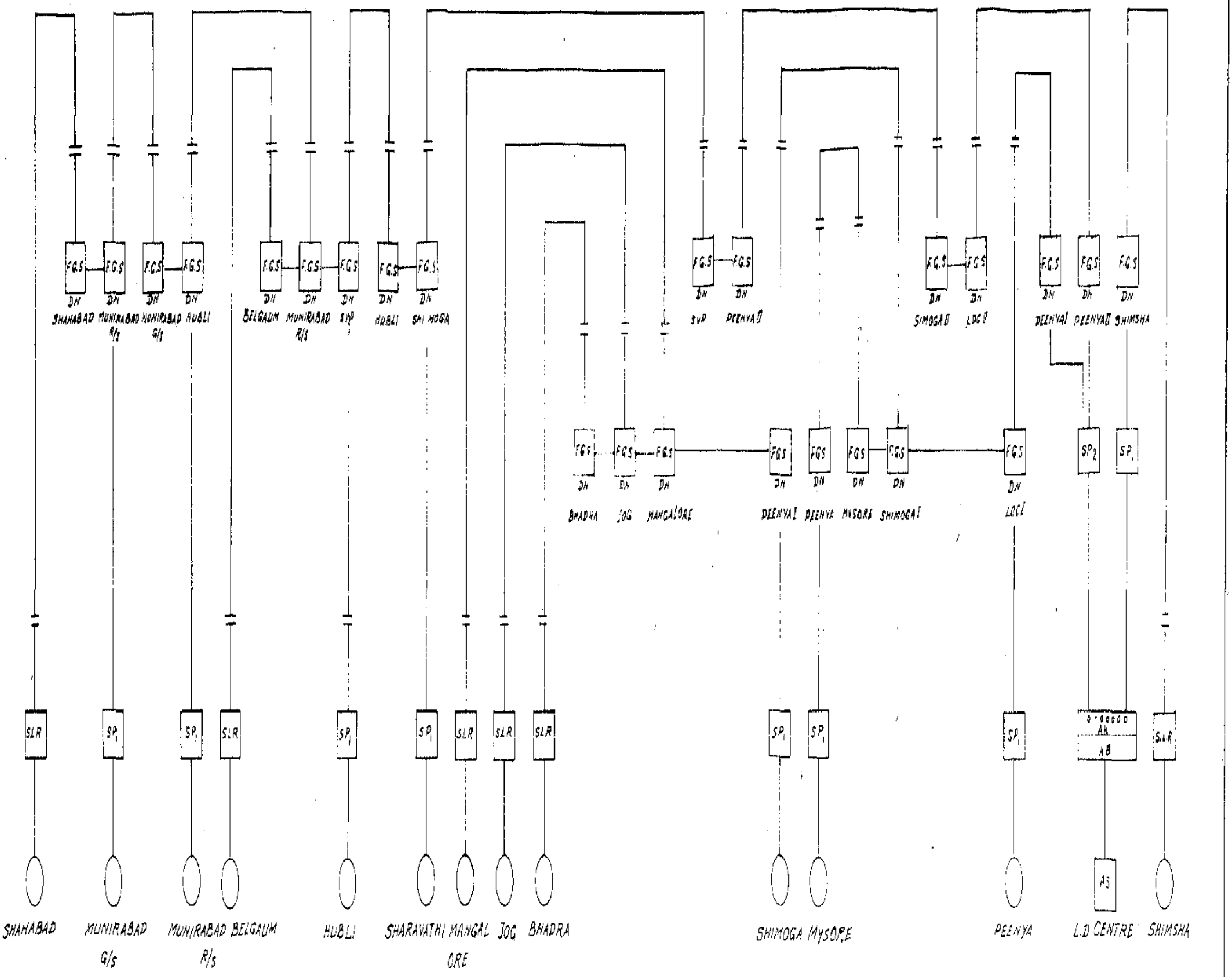


EXHIBIT. 10_MONTHWISE MAXIMUM DEMANDS DURING 1973-74

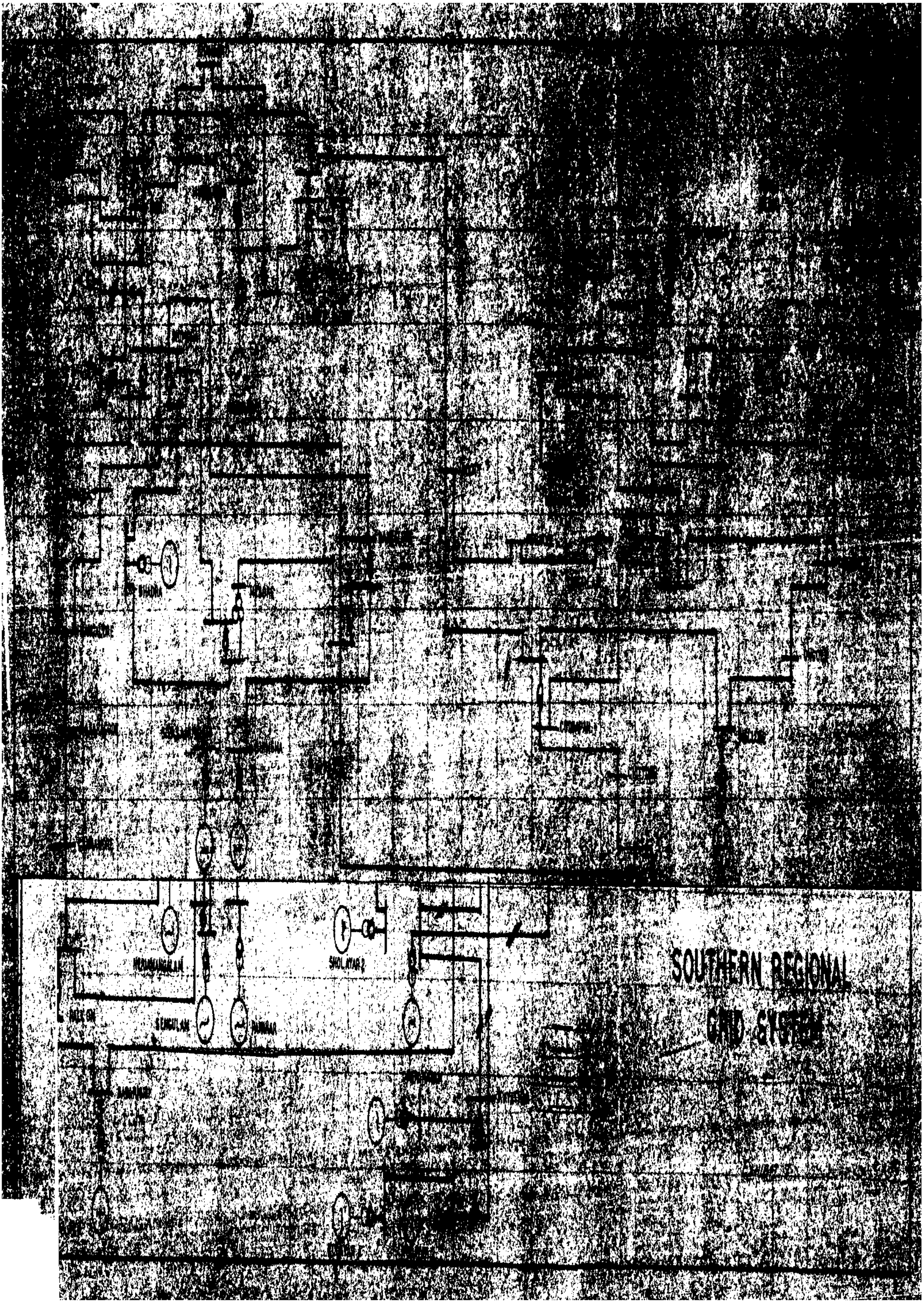


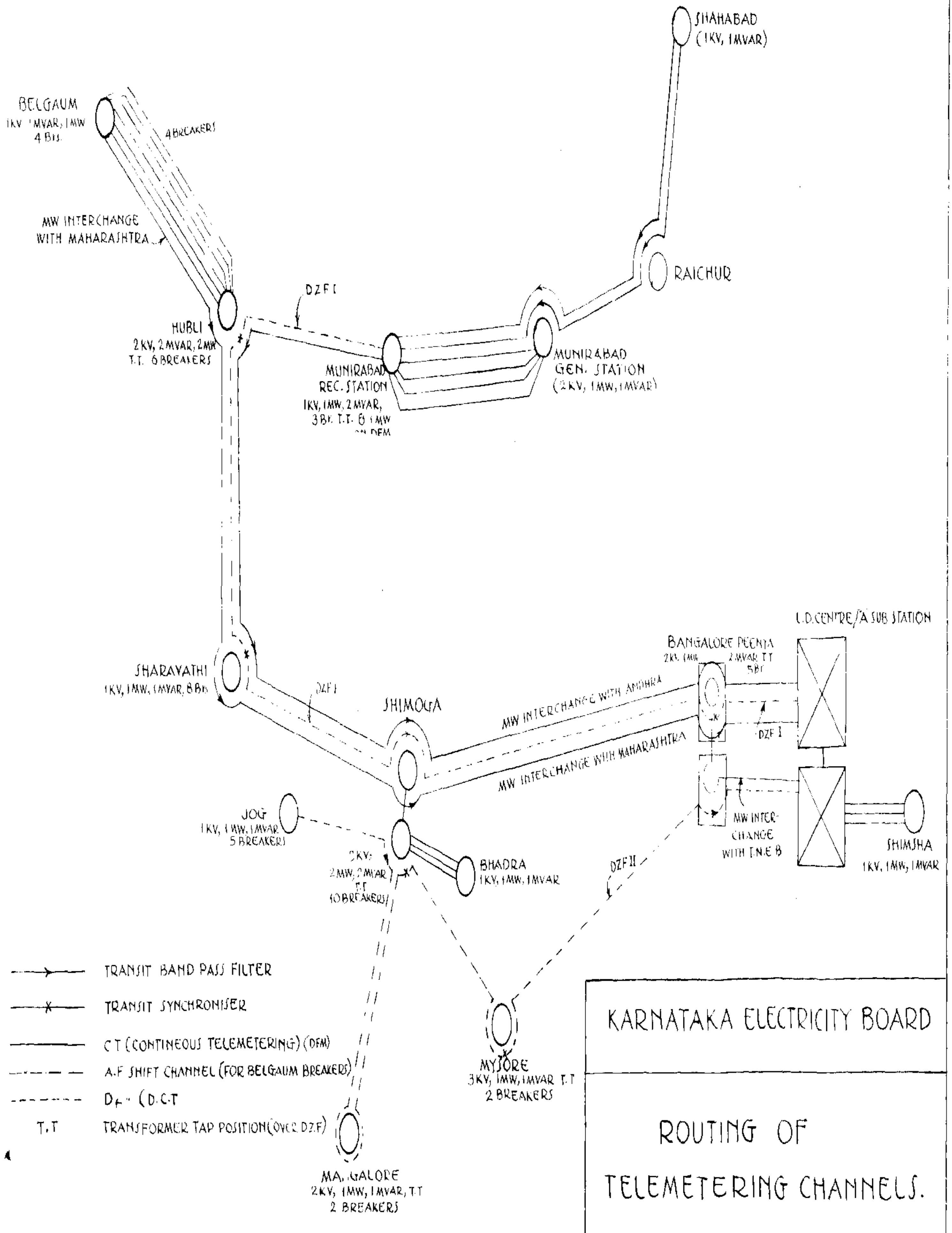
LEGEND		GROUPING OF STATION	
F.G.S	I.T.I FOUR WIRE GROUP SELECTOR	GROUP I LDC	SHIMSHA
SP1	ALBISWERK PANEL AWS 177/28P [SUITABLE FOR ONE SUBSCRIBER]	GROUP II LDC [6 STATIONS]	PEENYA OR MYSORE OR SHIMOGA OR BHADRA OR JOG OR MANGALORE
SP2.	ALBISWERK PANEL AWS 177/28C [SUITABLE FOR TWO SUBSCRIBERS]	GROUP III LDC [6 STATIONS]	SHARAVATHI OR HUBLI OR BELGAUM OR MUNIRABAD R/S OR MUNIRABAD G/S OR SHAHABAD
SLR.	SINGLE LINE REPEATER		
AK.	AUTOMATIC KEY COLLER		
AS	OPERATORS SWITCH BOARD		
AB	OPERATORS CIRCUITS		

EXHIBIT. II

KARNATAKA POWER GRID

AUTOMATIC TELEPHONY NETWORK [EXPRES CALLING SYSTEM]


SOUTHERN REGIONAL
GRID SYSTEM
BHADRA
SHOLAYAR 2
SENGULAM
PANNIAR

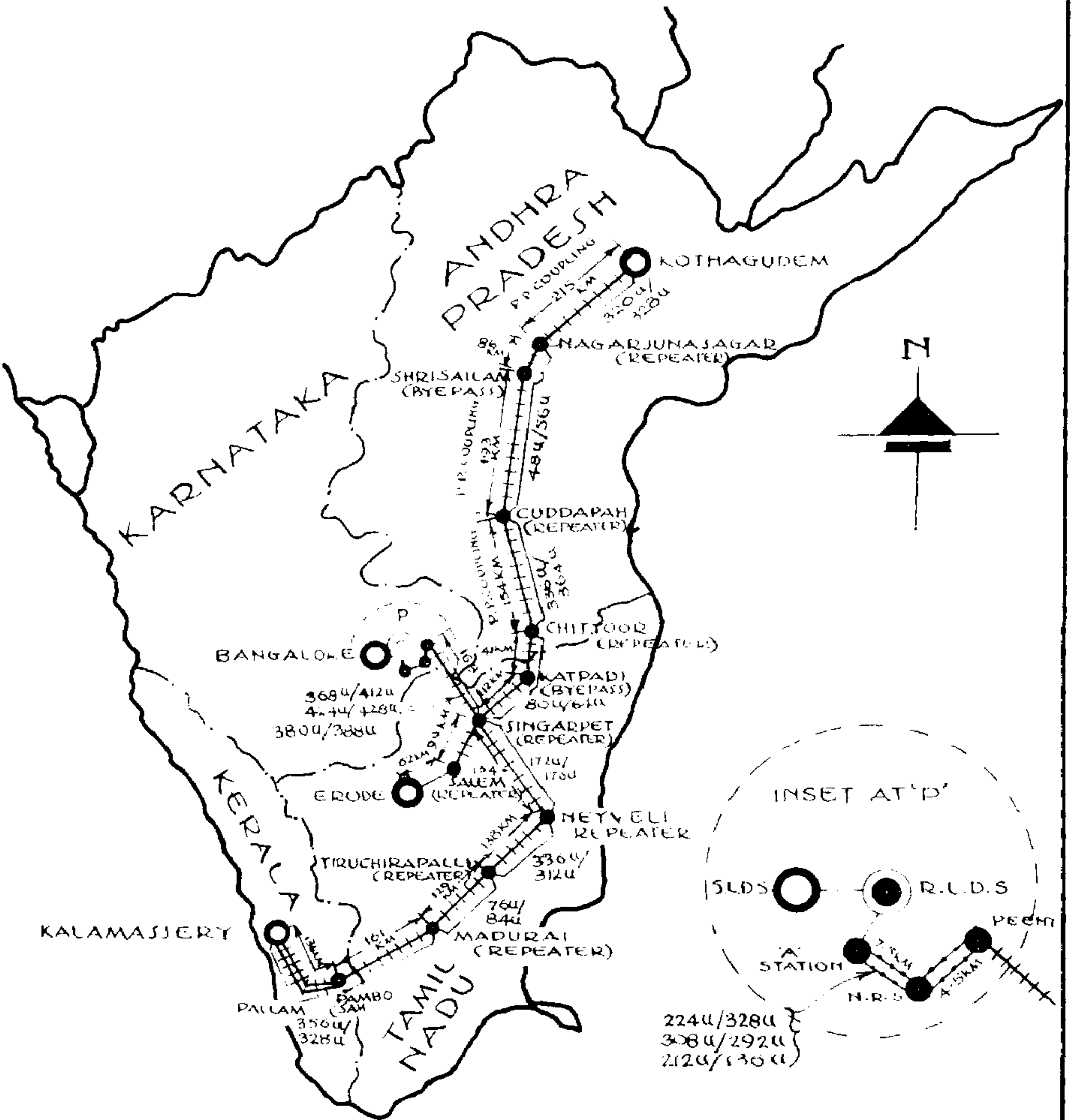


KARNATAKA ELECTRICITY BOARD

ROUTING OF TELEMETERING CHANNELS.

EXHIBIT 12

MAP SHOWING THE POWER LINE CARRIER NETWORK BETWEEN REGIONAL & STATE LOAD DESPATCHING STATION.



REGIONAL LOAD DESPATCHING STATION

STATE LOAD DESPATCHING STATION

SUB-STATION

220 K.V TRANSMISSION LINE

110 K.V. TRANSMISSION LINE

66 K.V. TRANSMISSION LINE

POWER LINE CARRIER COMMUNICATION.

EXHIBIT 13

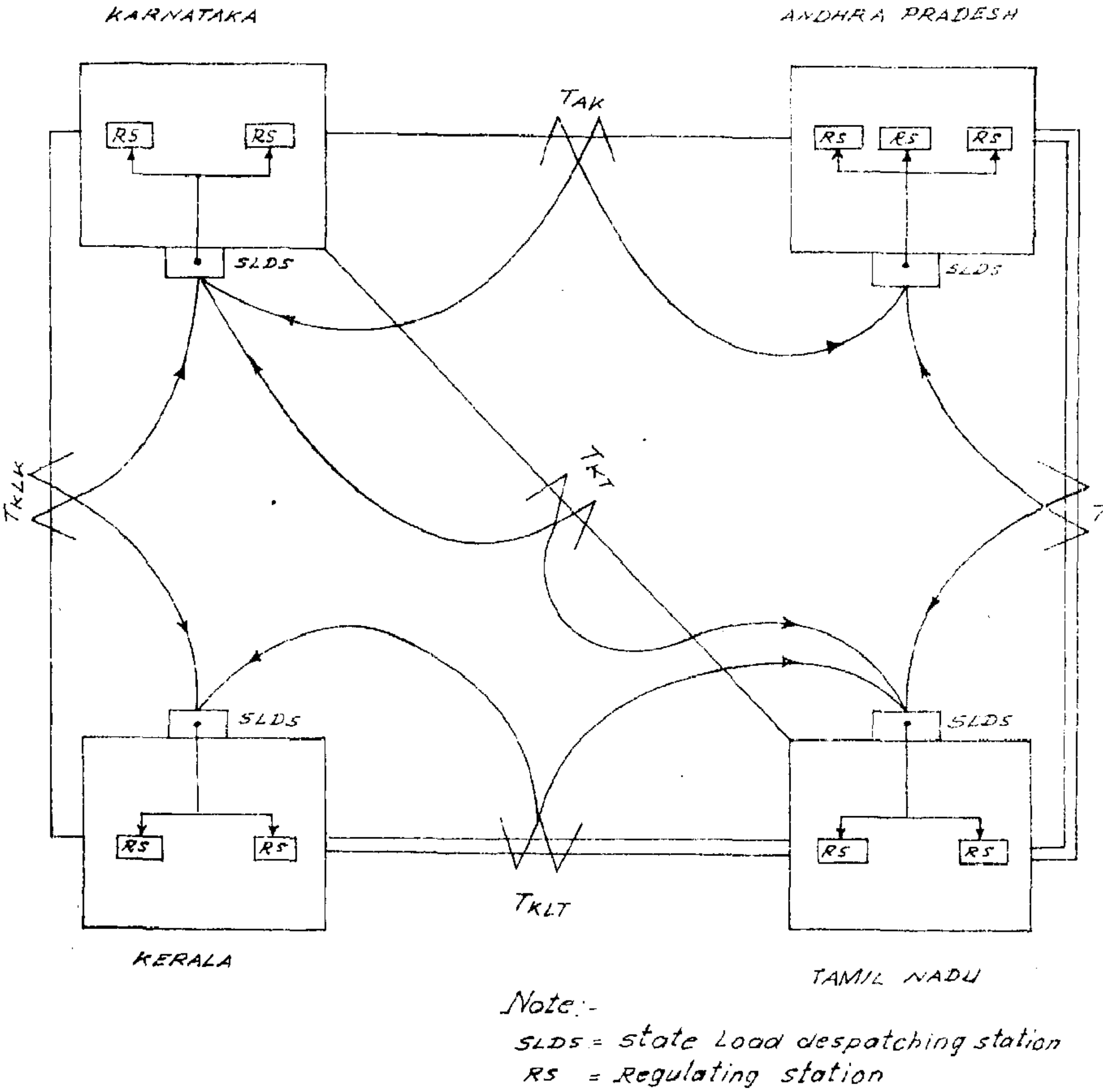


EXHIBIT-14 LOAD·FREQUENCY CONTROL·FOR SOUTHERN REGIONAL POWER SYSTEMS

CHAPTER - 9

CONCLUSIONS

9.1 The integrated operation of the Southern region has brought out an excellent spirit of cooperation among the constituent systems and has helped to tide over a number of emergencies thus improving the reliability of systems in a significant manner.

9.2 Much more benefits will accrue to the region by implementing the sophisticated methods of load despatching techniques.

9.3 Accurate load forecasting and optimum generation scheduling are the fundamental requirements and basic necessicity for an efficient and modern load despatching organisation. The forecasting of system loads and generation availability in the region shall be done on annual, weekly and daily basis and shall be supported by two hourly reviews. The generation schedules shall also be prepared on the same basis. The forecasting errors should be minimum as far as possible.

9.4 Regulation of tie line power and frequency are the important aspects to be considered for smooth and efficient operation of the regional power systems. Karnataka and Andhra Pradesh state electricity Boards have already procured sophisticated load frequency control equipments for the state load despatching stations. Tamil Nadu and Kerala State Electricity Boards should also procure and install similar type of equipments at the state load despatching stations. The region will be more benefitted and operating conditions will improve by installing load frequency control equipments at state load despatching stations and operating the systems on tie line load bias control basis.

The Southern regional Electricity Board should plan, installation of load frequency control equipment at the regional load despatching station only when the regional grid is fully developed (i.e. free flow of power in the lines) and after establishing number of inter-regional lines with the neighbouring systems.

9.5 The Tamil Nadu and Andhra Pradesh Electricity Boards should take initiative in establishing the state load despatching stations at Madras and Hyderabad respectively. Bangalore (where the Regional Load Despatching station is located) is connected with Madras and Hyderabad by P and T coaxial cable. Thus we can utilise the P and T channel for communication, from the regional load despatching stations to state load despatching stations in addition to power line carrier communcation. Further this will also enable the load despatchers (at Madras and Hyderabad) to take quick decisions in some of the operational problems such as power flows in inter-state/regional lines etc. after consulting with the Chairman or the Chief Engineer's of the respective systems.

The Southern regional power systems should avail P and T facilities (coaxial cable/microwave links) for communication to the maximum extent possible in order to secure 100% reliable communication, so that the load despatcher would be in a position to discharge his functions smoothly and uninterruptedly.

9.6 The Southern region with the joint venture of all the four states should plan in exploring all hydro power potentials available in the region, being the cheapest source of power and will bring down incremental cost of generation in the region. The water resources avilable in the region should be utilised to the maximum extent possible in most economical manner.

9.7 The power systems in the region should install extensively under frequency relays at various grid stations in the system for load shedding, in case of an outage of generating units. This will enable the systems to maintain uninterrupted power supply to essential services.

9.8 The total installed capacity of the Southern region at the end of V plan will be order of 8973 Mw comprising 6121 Mw hydro and 2852 Mw Thermal. More number of hydro and thermal plants are anticipated in the region in subsequent plan periods. The power systems in the region should install automatic load despatching computers in the state load despatching stations in view of the rapid load development in the region, and for operation of the systems more economically.

The southern region should also install a digital computer at the regional load despatching station for conducting studies and other operational problems pertaining to the system.

9.9 The Regional Electricity Board should take up long term planning of the region and to conduct studies to identify the transmission and generation requirements etc. in the region and these works should be carried out by the constituent systems in phased manner.

9.10 The Regional Electricity Board should also plan more number of inter-state lines of adequate capacity (considering the outages of generating units) for reliable operation of the region on integrated basis.

More operational benefits such as reliability, spinning reserve requirement, economic operation of units etc. will accrue to the regional grid after implementing some of the load despatching techniques enumerated above.

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UNIVERSITY OF ROORKEE
ROORKEE

REPORT OF THE EXAMINERS FOR AWARD OF M.E.DEGREE

NAME OF CANDIDATE B.CHIKKA KALAPPA
DEPARTMENT W.R.D.T.C.
SPECIALISED SUBJECT LOAD DESPATCH TECHNIQUES

The candidate has done useful studies and will be of good use for him as well as for others and his state.

Sd/- External Examiner

xxxxxx

University of Roorkee
Roorkee

No.Ex/ /E-139 Dated Feb. ,1976.

Copy forwarded to:-
1. Prof. & Head of Department W.R.D.T.C.
2. Sri Brijesh Chandra, Reader W.R.D.T.C.

Chhabra

(G.G.Chhabra)
Asstt. Registrar (Exam.)