Assignment - 01

1) what are the states of power system Explain in brief with suitable diagram.

Ans :- The system states are classified as,

1. Normal state
2. Alert State
3. Emergency state
4. Extremis state
5. Restorative state

1. Normal state :-

*) A system is said to be in normal if both load and operating constraints are satisfied.

*) It is one in which ~~to~~ the total demand on the system is met by satisfying all the operating constraints.

2. Alert State :

* A normal state of the system said to be in alert state if one or more of the postulated Contingency states, Consists of the Constraint limits violated.

→ when the system security level falls below a certain level or the probability of disturbance increases, the system may be in alert state.

→ All equalities and inequalities are satisfied but on the event of a disturbance, the system may not have all the inequality constraints satisfied.

→ If severe disturbance occur, the system will push into emergency state. To bring back the system to secure state, preventive control action is carried out.

3. Emergency state:

* The system is said to be in emergency state if one or more operating constraints are violated, but the load constraint is satisfied.

→ In this state, the equality constraints are unchanged.

→ The system will return ~~or~~ to the normal or alert state by means of corrective actions, disconnection of faulted section or load sharing.

4. Extremis state:

when the system is in emergency, if no proper corrective action is taken, then it goes to either emergency state or extremis state.

→ In this regard neither the load or nor the operating constraint is satisfied. this result is islanding.

→ Also the generating units are strained beyond their capacity.

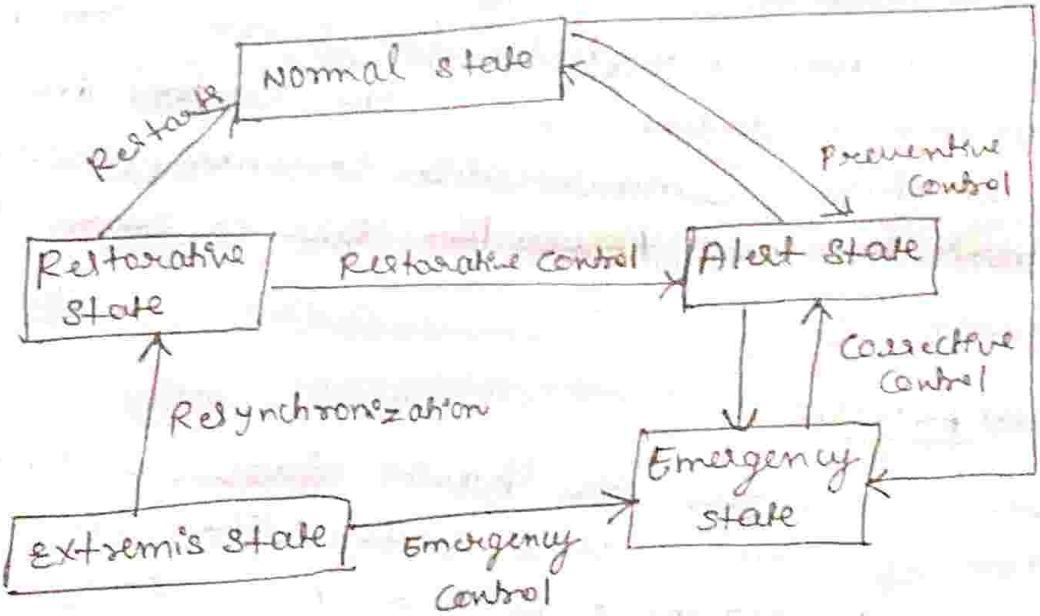
→ So emergency control ~~is do~~ action is done to bring back the system state either to the emergency state or normal state.

5. Restorative State :

From this state, the system may be brought back either to alert state or secure state. The latter is a slow process.

→ Hence, in certain cases, first the system is brought back to alert state and then to secure state.

→ This is done using restorative control action



2) Explain major components of Energy Management Centre.

Ans :- The four major components of the energy management centres are as follows :-

1. SCADA :-

The SCADA system consists of two subsystems - the supervisory control and data acquisition. The supervisory subsystem is responsible for :-

(a) display at the central location the status of the circuit breakers and other devices such as tap changers, capacitor switching, generator voltage regulator;

(b) facilitating remote tripping of breakers; tap changing of transformers, etc.

The dispatcher at the control centre will initiate actions to switch circuit breakers, change taps, etc.

The data acquisition subsystem consist of the Remote Terminal Units (RTUs) to interface the power system instrumentation with the control devices and interface communication channels (wireless communication and Power line carrier communication (PLCC) systems) and control centres.

2. <u>Computers:-</u>

Modern computers are having immense capabilities in terms of memory and speed. The structure of energy management centres has changed with advent of fast computing facilities.

Since the applications are crucial, redundancy is built in the hardware. Different schemes are available for backup.

The main functions of the computing facilities at the control centre are as follows:-

* Real-time monitoring and control
* User-interface
* Operating studies
* maintenance and testing

* Simulation Studies.

3. <u>User interface</u> (with extensive GUI and display facilities):

The user interface consists of consoles, data logger, display unit and screen projections to alert operator. Since there is extensive interaction with human beings, modern interfaces use techniques of animation and extensive graphics to make it more user friendly.

4. <u>Application software</u>:

This section is to implement the various functions discussed, namely, unit commitment (UC), economic dispatch, state estimation, optimal power flow, contingency analysis etc.

3) Explain the key concepts for reliable operation of power system.

Ans:- Key concepts for reliable operation of PS:

1. <u>Balance the generation And load</u>

The AGCs are ~~A~~ used to match the generation with changing load. Failure to match generation with the demand will cause frequency deviation. The frequency ~~d~~ increases if generation exceed demand and it decreases when demand exceeds generation.

Large variation in frequency is detrimental to the life of the equipment.

2. Balance Reactive Power:-

The reactive power sources are generators and capacitors banks. The generator automatic voltage regulators control voltage levels of generators. Today, FACTS controllers are commonly used for reactive power control.

3. Ensure Thermal limits are not exceeded:

The heating limits of overhead lines must not be exceeded, otherwise the lines will sag. There are many critical black outs which have resulted due to sagging of lines, leading to short circuits, relay tripping and ultimately grid collapse.

4. Maintains systems stability:-

If a system loses stability, the grid may face a total collapse. The stability limits will specify the maximum power that can be transferred over lines.

5. Meet N-1 reliability criteria

This means that the system should remain operational and secure even after the loss of the largest generator in the system

6. Plan, Design and maintain to operate Reliably.

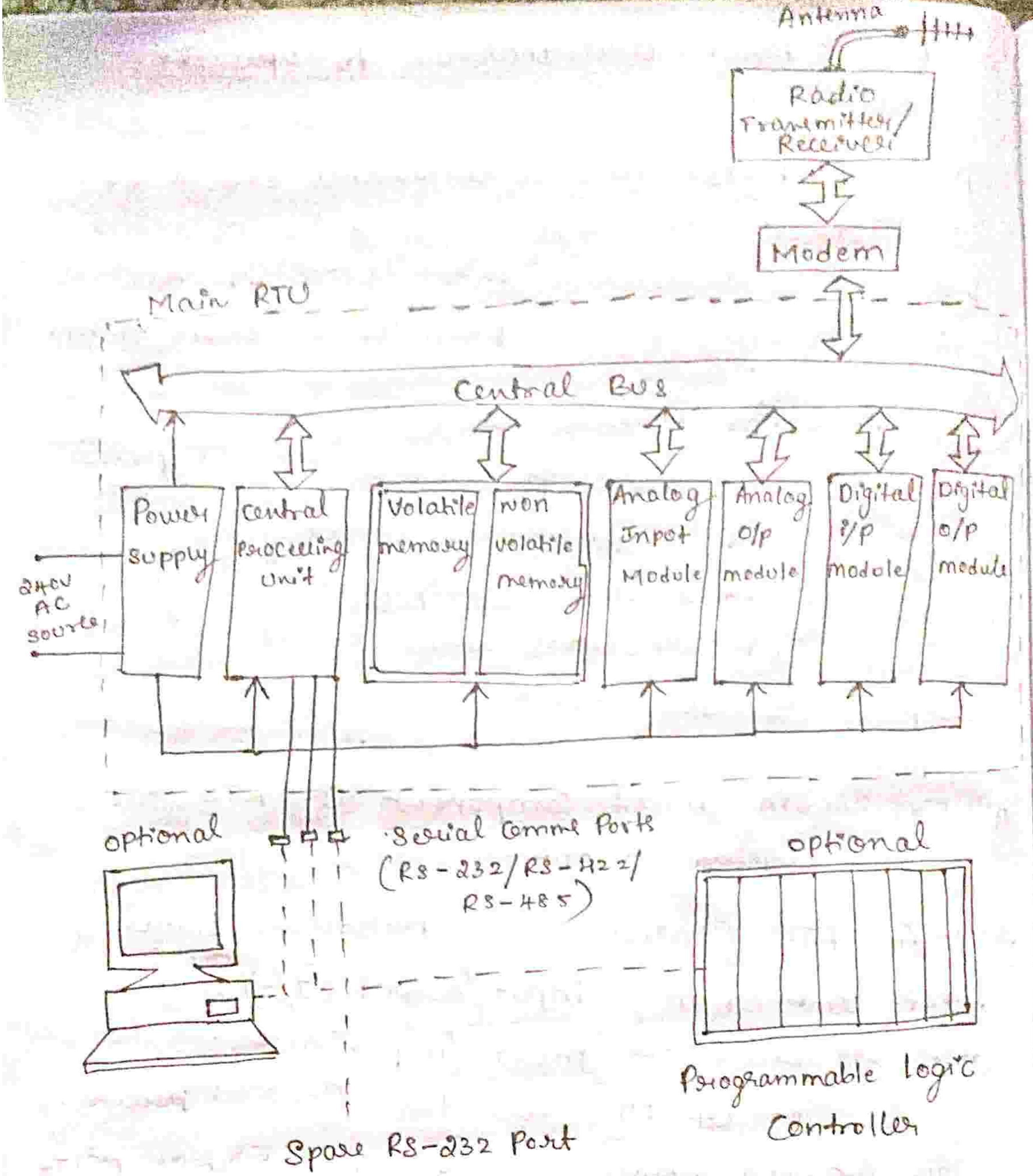
Planning, Design and maintenance should be such that the system should be operated reliably and within safe limits at all times. Planning involves both long & short term.

7. Prepare for Emergencies:

In spite of thorough planning and good design. Emergencies such as weather fluctuations, operator error, software failure, equipment failure, etc can occur. Operators must be trained to prepared for such emergencies.

4) Explain in brief components of RTU for power system SCADA.

Ans:- An RTU consists of a hardware Panel where one or more input/output (I/O) modules are installed. The most important Components of RTU are the Central processing Unit (CPU), power supply, Communication port, and physical I/O; ~~we will~~



* Central Processing Unit (CPU)

The CPU may consist of one or more complex circuit cards that execute central function processing. Modern RTUs use 32-bits microprocessors. The CPU makes use of a watchdog timer to validate that the cycle execution is done correctly.

The CPU module may also be equipped with ethernet Communication ports. Some RTUs Come with dual CPUs, in which case, they are configured as primary and backup, providing redundancy to the device.

* Power supply

RTUs are normally supplied with continuous power from a main line. However, the remote locations where RTUs may be installed are also typically provisioned with backup battery modules. This can help ensure uninterrupted operation for a period of time. The most Common type of battery used is lead-acid, although lithium batteries have been gaining popularity more recently.

* Communication Ports

Every RTU needs a way to Communicate to the outside with client (or master) SCADA station. To achieve this, they are equipped with at least one Communication port. RTUs support many communication protocols, including Ethernet, RS-232, and Modbus. Some of the most common topologies supported in RTU and SCADA networks are ring, series, star, etc.

* Physical I/O

RTUs support the four most common I/O modules: digital input, digital output, analog input, and analog output. Digital input modules capture status and alarm signals coming from the field devices. Digital output is necessary to send signals and commands to the field devices. Analog inputs and outputs work with variable current or voltage, nomally in the 0-1mA or 0-10V ranges, respectively.

5) with usual notations, explain the following with reference to scada system.

i) AGC

A: It is similar to SCADA, except that AGC capabilities are included to calculate the area control error, monitor system frequency and tie-line interchanges and perform economic dispatch.

(ii) EMS

A: Energy management systems incorporate all features of SCADA and also includes other computations, such as load flows, state estimation contingency analysis, etc. It includes extensive capabilities of record keeping and data exchange.

(iii) DMS

Distribution management systems are meant to monitor and Control distribution feeder loads. DMS today includes topology analysis and load flow programs that allow identification of problems and restoration of services.

(iv) LMS

Load management system is meant to manage the peak load and is useful for demand-side management. It can be a stand-alone program or integrated into EMS or DMS.

(v) AMR

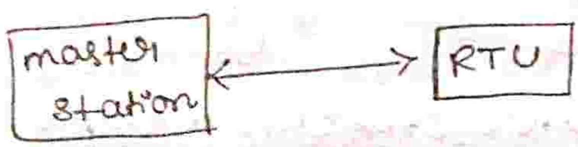
Automatic meter reading is incorporated into LM systems.

6) Explain the classifications of SCADA system.

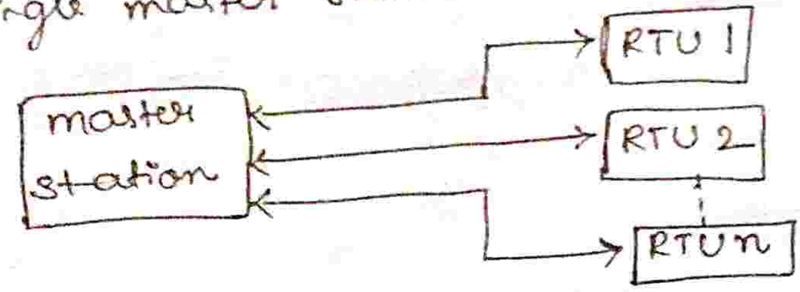
Ans:- The master station and RTUs can be connected in a number of different ways. They are shown as follows.

1. Single master station configuration.

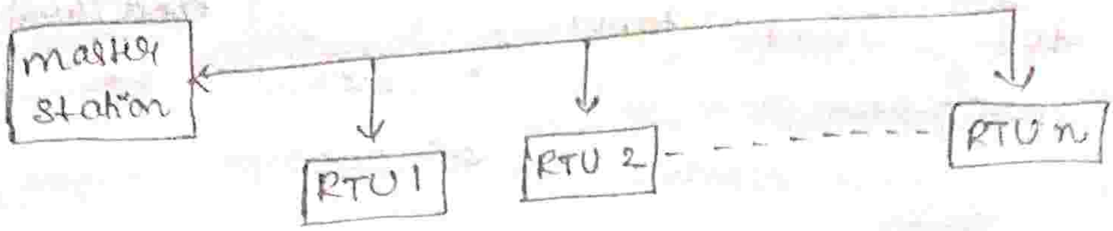
(a) single master station and single RTU



(b) single master station ~~with~~ and multiple RTUs

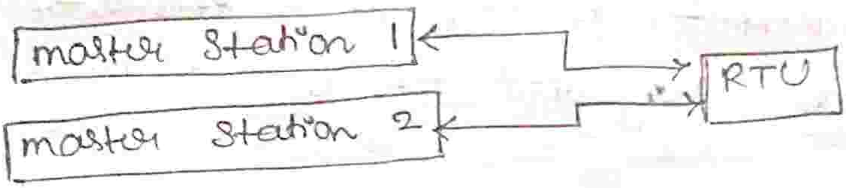


(c) single master station and multiple RTUs in multiple circuit

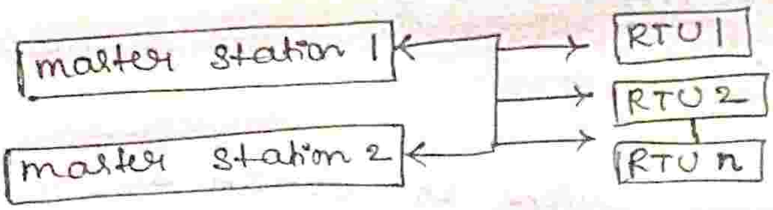


2. multiple master station configurations

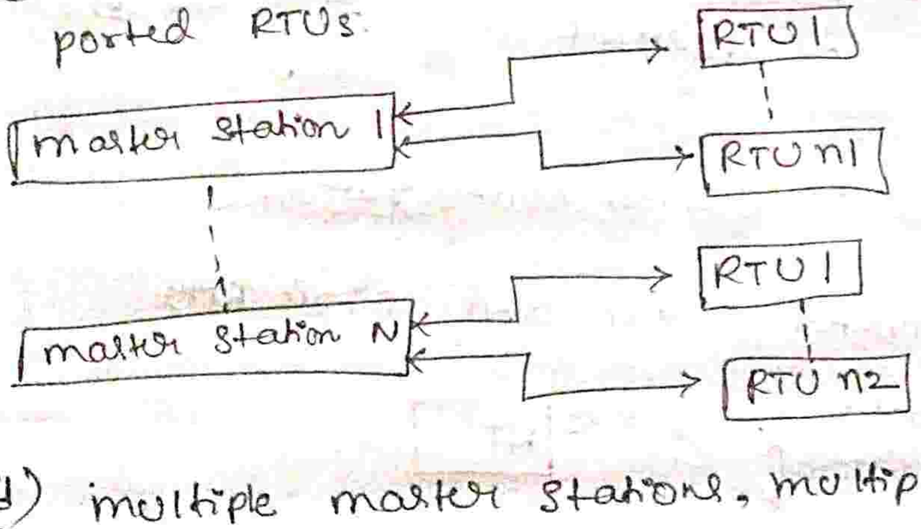
(a) single dual ported RTU, radial ckt



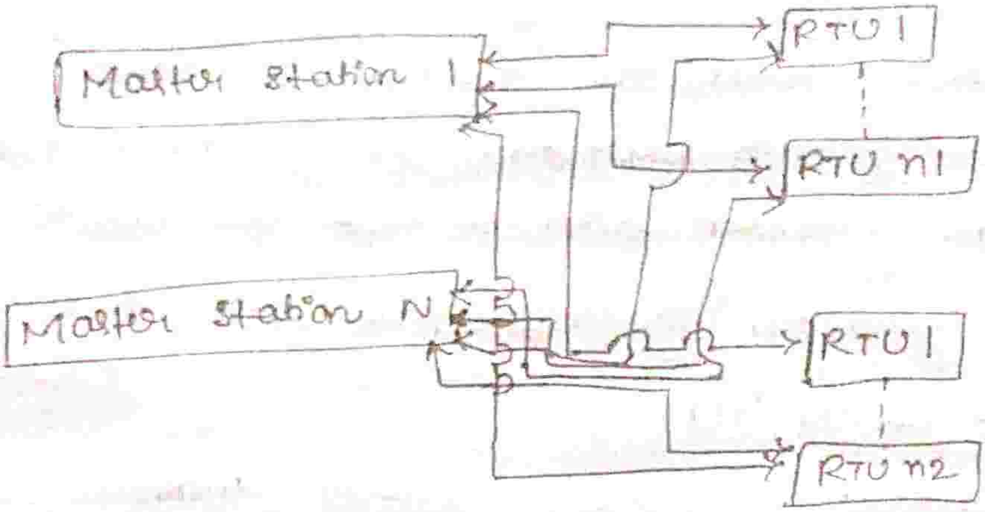
(b) multiple RTUs, multi-drop ckt



(c) multiple master stations, multiple single ported RTUs

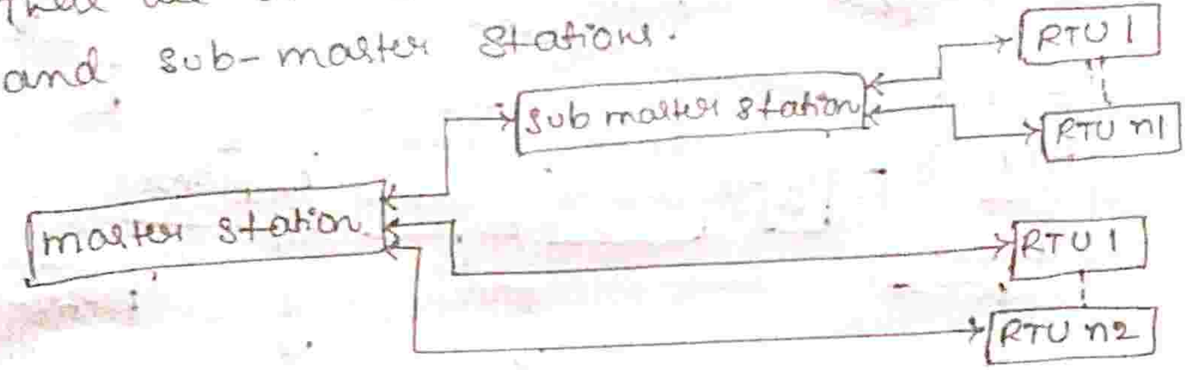


(d) multiple master stations, multiple dual ported RTUs

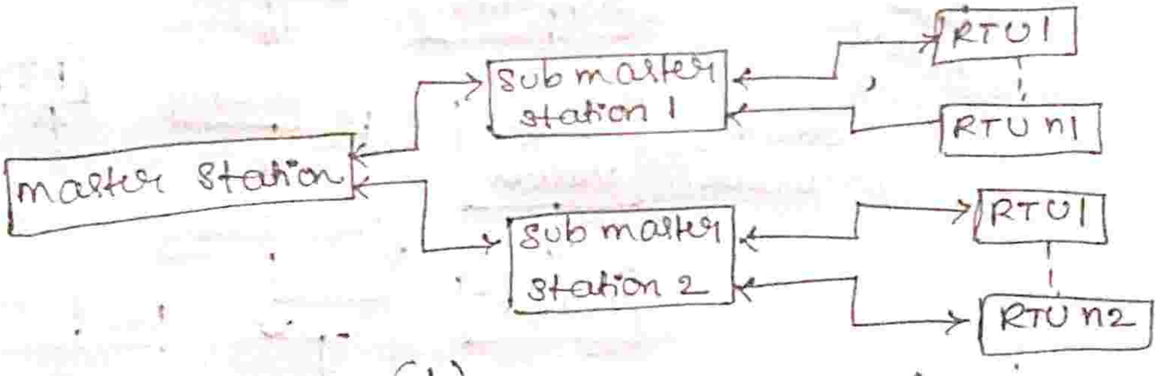


3. Combination sytems

There are a combination of master stations and sub-master stations.



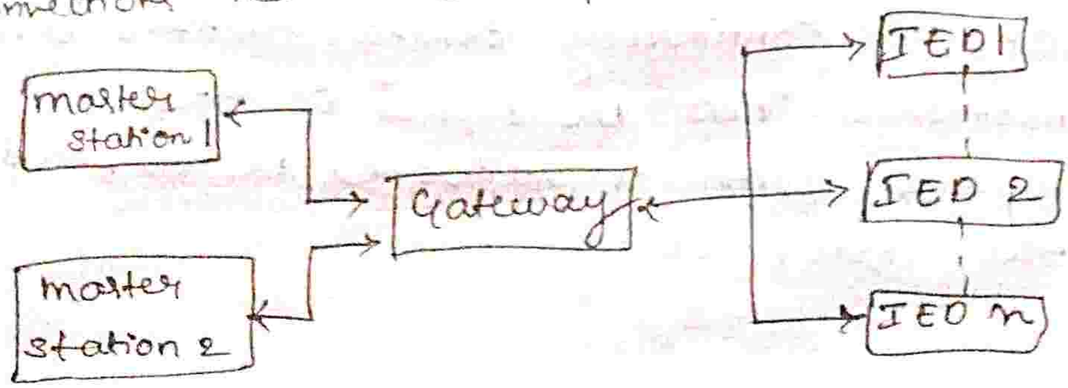
(a)



(b).

4. Gateway Connections.

With the prolific use of Etheenet Gateway Connections have become popolar

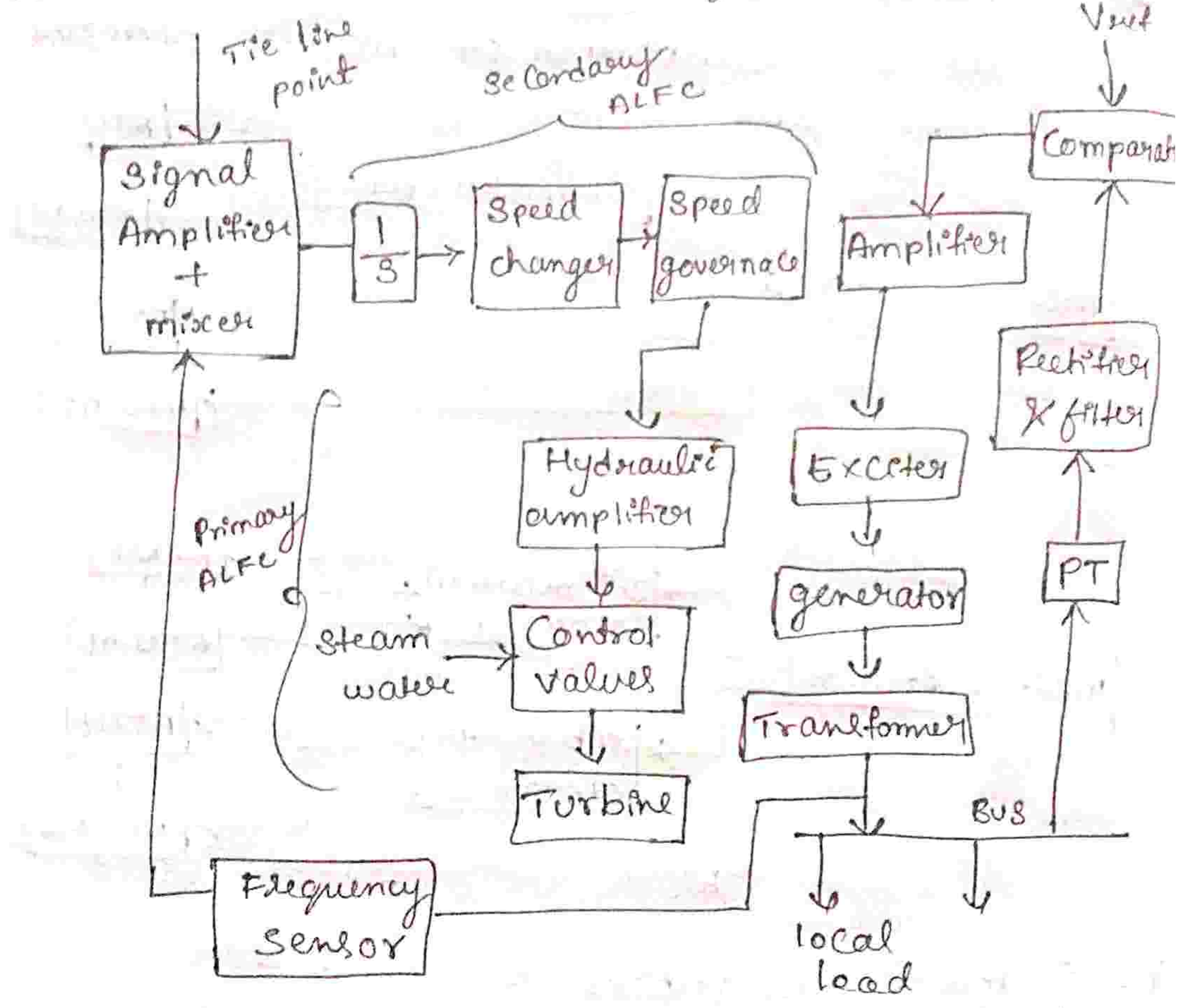


7) Explain in brief the function of load frequency control & excitation voltage regulation of turbo generator with a neat diagram.

Ans: The generator are equipped with two major control loops

① Automatic voltage regulator (AVR)

② Automatic load frequency control (ALFC)



* To implement the AVR, the terminal voltage is continuously sensed, rectified and smoothened. This DC signal is then compared with a reference DC to produce the error voltage

* This Error voltage is amplified and is used as a input to the Exciter to adjust the field current in such a way that the terminal voltage reaches the reference value.

* The ALFC Controls the real power so as to maintain the system frequency constant. This is achieved by Controlling the speed of the prime mover.

* The ALFC has two loops, the first primary loop which responds to ~~the first primary loop which re~~ frequency changes and regulates the steam or water flow to the turbine.

* The time period Considered is few seconds this ~~fr~~ primary loop performs a coarse speed or frequency control.

* The slower secondary loop which maintains fine frequency, adjustments to maintain proper active power, interchanged with other interconnected N/w through tie lines.

* This loop is insensitive to ~~fast~~ load & frequency changes and acts on deviations ~~that~~ take place over several minutes

8) Draw the schematic diagram of speed turbine speed governing system and Explain the functions of various Components.

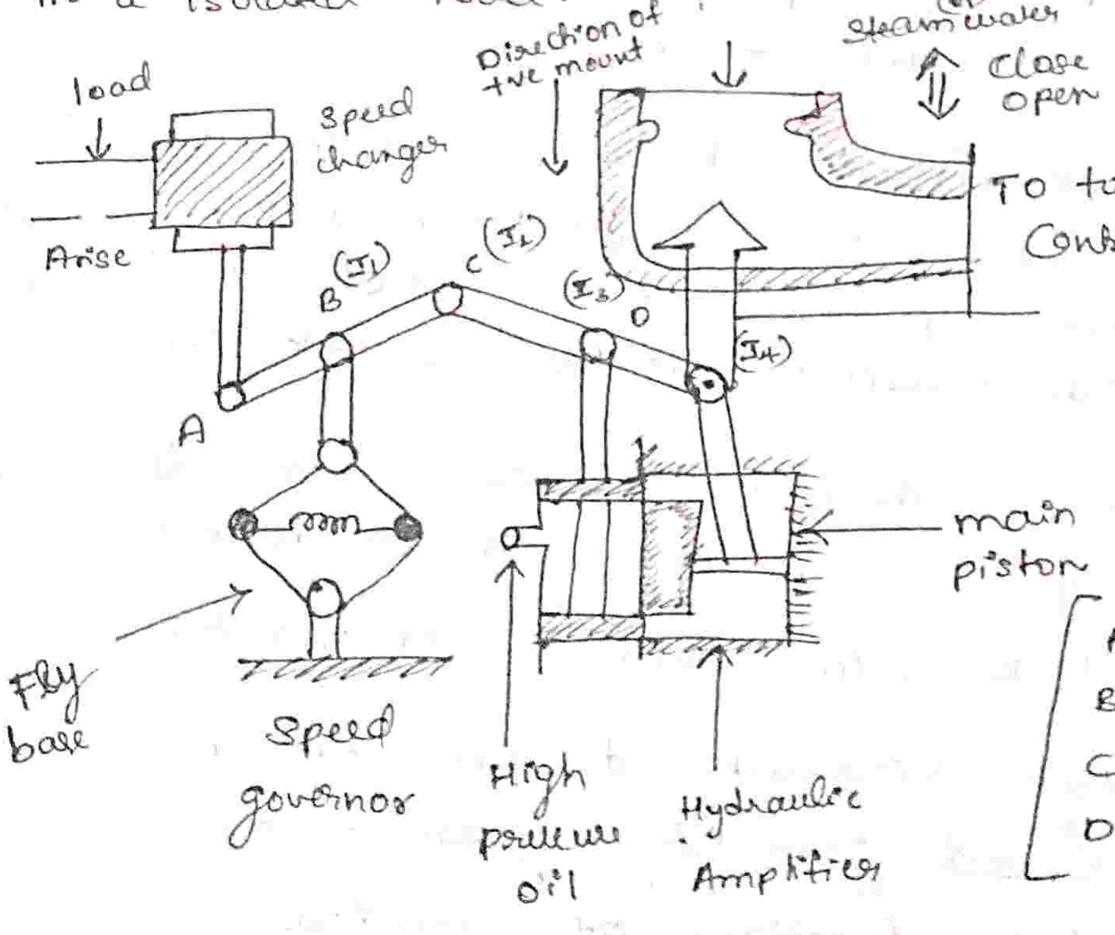
Ans :-

Consider the problem of Controlling the power output of inter connected generator's . so, as to maintain the schedule frequency.

All the generator's in such an area constitute a cohoent group, so that all the generators speed up and slow down together maintaining their relative power angle's. Such an area is defined as Control area.

The boundary's of an Control area will generally Co-inside with that of a individual ~~electrically~~ electricity company.

To understand the load frequency control, Consider a single turbo generator sytem supplying in a isolated load.



$$\begin{bmatrix} A-B = I_1 \\ B-C = I_2 \\ C-D = I_3 \\ D-E = I_4 \end{bmatrix}$$

The system consists of the following components :-

1) Flyball speed governor :

This is the heart of the system which senses the change in speed as the speed increases the flyballs move outwards and the point B is moved downwards. The reverse happens when speed decrease.

2) Hydraulic Amplifier :-

It comprises a pilot value and main piston arrangement. when pilot value moves upwards the High pressure oil enter the main piston at the top, and moves the control valve towards open. when pilot value moves downwards the High pressure oil will enter the main piston from bottom and pushes the piston towards close.

3) Linkage mechanism :-

A, B, C is a rigid link pivoted at B and C. D, E is another rigid link pivoted at D. This link mechanism provides a movement to the control value in proportion to change in speed. It also provides a feedback from Steam valve movement.

4) Speed changer

It provides a steady state power output setting for the turbine. Its downward movement opens the upper pilot value, so that more Steam is admitted to the turbine under

Steady st Conditions which will produce more power outputs. The reverse happens for the upward movement of the speed changer.

9) Explain the modelling
i) speed governor system model
ii) turbine model
iii) Generator load module & draw complete block diagram.

As :- i) Speed governing system model

Under steady condition turbine runs at Constant Speed with turbine power output balancing generation load.

The parameters under this Conditions are :

$f^{\circ} \rightarrow$ system frequency

$P_G^{\circ} \rightarrow$ generator output

$Y_R^{\circ} \rightarrow$ steam valve setting

let A point on the linkage mechanism be moved downwards by a small amount ΔY_A.

$$\Delta Y_A = K_c \Delta P_c \longrightarrow (1)$$

$\Delta P_c \rightarrow$ is the Commanded increase in Power

The Command signal ΔP_c sets into motion a sequence of events, the pilot valve moves upwards High pressure oil flows onto the top of the main piston moving it downwards, the steam valve opening increases, the turbine generator speed increases and frequency goes up.

$-\left(\frac{l_2}{l_1}\right)\Delta Y_A$

$= -K_1 K_c \Delta P_c$

The increase in frequency Δf causes the flyballs to move outwards so that B moves downwards by a proportional amount i.e., $K_2' \Delta f$

The consequent movement of C with A remains fixed at ΔY_A is

$$\left[\frac{l_1+l_2}{l_1}\right] K_2' \Delta f = K_2 \Delta f$$

The net movement of C is therefore,

$$\Delta Y_C = -K_1 K_c \Delta P_c + K_2 \Delta f \longrightarrow (2)$$

The movement of D, i.e., ΔY_D is the amount by which the pilot valve opens

$$\Delta Y_D = \left(\frac{l_4}{l_3+l_4}\right)\Delta Y_C + \left(\frac{l_3}{l_3+l_4}\right)\Delta Y_E$$

$$\Delta Y_D = K_3 \Delta Y_C + K_4 \Delta Y_E \longrightarrow (3)$$

The movement of ΔY_D opens one of the ports of the pilot valve admitting high pressure oil into the cylinder, thereby moving the main piston & opening the steam valve by ΔY_E

The volume of oil admitted to the cylinder is proportional to the time integral of ΔY_D

$$\Delta Y_E = K_5 \int_0^t -(\Delta Y_D)\, dt \longrightarrow (4)$$

Taking laplace transformation (2) (3) (4)

$$\Delta Y_C(s) = -K_1 K_C \Delta P_C(s) + K_2 \Delta F_C(s)$$

$$\Delta Y_D(s) = K_3 \Delta Y_C(s) + K_4 \Delta Y_E(s)$$

$$\Delta Y_E(s) = \frac{-K_5}{s} \Delta Y_D(s)$$

Substitute $\Delta Y_D(s)$ & $\Delta Y_C(s)$ in $\Delta Y_E(s)$

$$\Delta Y_E(s) = \frac{-K_5}{s}\left(K_3 \Delta Y_C + K_4 \Delta Y_E\right)$$

$$= \frac{-K_5}{s}\left(K_3\left(-K_1 K_C \Delta P_C(s) + K_2 \Delta F_C(s)\right) + K_4 \Delta Y_E(s)\right]$$

$$\Delta Y_E(s)\left[1 + \frac{K_4 K_5}{s}\right] = \frac{K_1 K_3 K_C K_5}{s} \Delta P_C(s) - \frac{K_5 K_2 \Delta F_C(s)}{s}$$

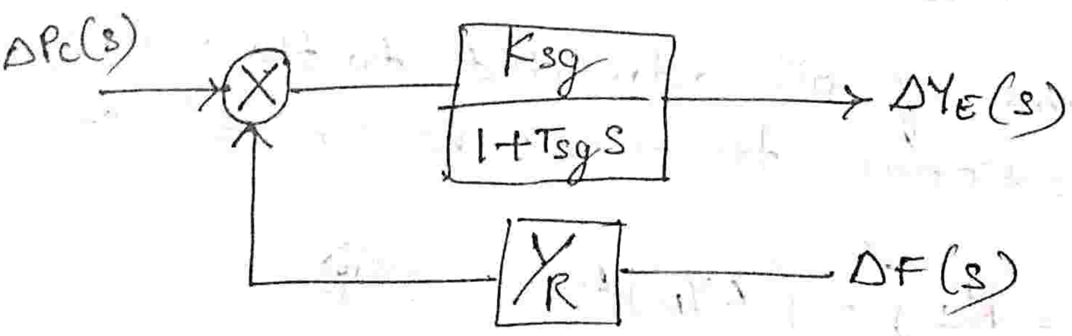
$$\Delta Y_E(s) = \frac{K_1 K_3 K_C \Delta P_C(s) - K_2 K_3 \Delta F(s)}{\left(K_4 + s/K_5\right)}$$

$$= \left[\Delta P_C(s) - \frac{1}{R}\Delta F(s)\right] \times \left[\frac{K_{sg}}{1 + T_{sg} s}\right]$$

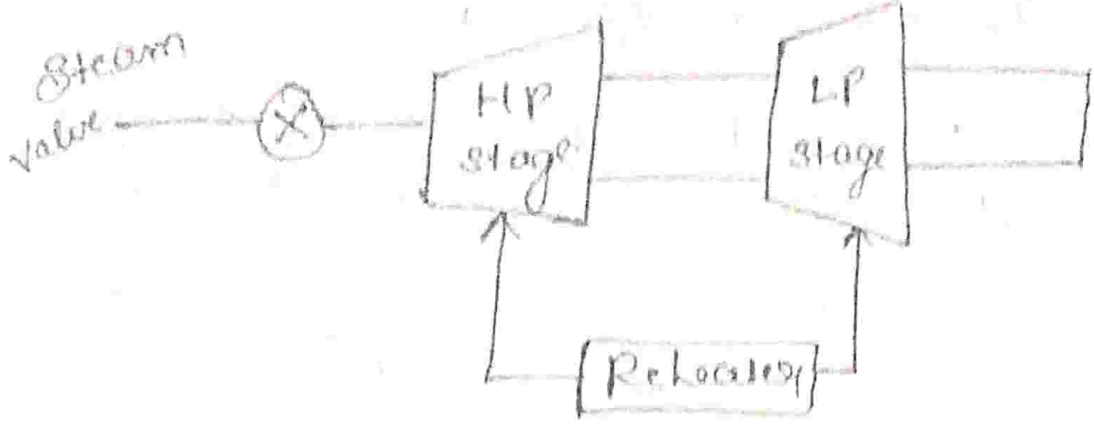
$$R = \frac{K_1 K_C}{K_2}$$ = Speed Regulation of Governor

$$K_{sg} = \frac{K_1 K_3 K_C}{K_4}$$ = Gain of Speed Governor

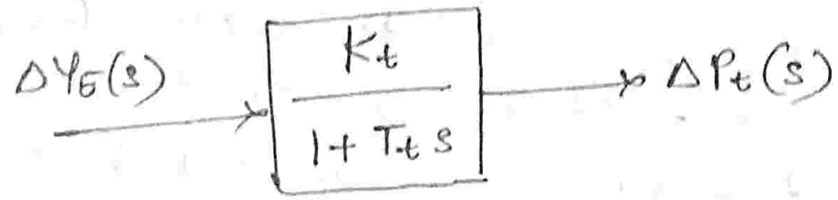
$$T_{sg} = \frac{1}{K_4 K_5}$$ = Time Constant of Speed governor.



(ii) Turbine Model



* The figure shows a steam turbine with a reheater unit.
* The dynamic response is largily influenced by two factors
 i) Entered steam between inlet steam value & first stage of a turbine.
 ii) The storage action in the reheater which causes o/p of the low pressure stage to lag behind the top high pressure stage.



(iii) Generator load Model

The increment in power i/p to the generator load system is $\Delta P_G - \Delta P_D$

where, $\Delta P_G = \Delta P_t$ incremental turbine power i/p
 & $\Delta P_D \rightarrow$ is the load increment.

The rate of increase of stored 'Kinetic' Energy in the generator is $W^{\circ}_{ke} = H \times P_r\, kW$.

where, $H \rightarrow$ inertia Constant

$P_r \rightarrow$ generator o/p in KW.

The kinetic energy being proportional to square of speed, the kinetic energy at a frequency $(f^0 + \Delta f)$ is

$$W_{ke} = W_{ke}^0 \times \left(\frac{f_0 + \Delta f}{f_0}\right)^2$$

$$W_{ke} = W_{ke}^0 \left[1 + \frac{\Delta^2 f}{f_0^2} + \frac{2 \Delta f \times f_0}{f_0^2}\right]$$

is neglible.

$$W_{ke} = W_{ke}^0 \times \left[1 + \frac{2\Delta f}{f_0}\right]$$

$$W_{ke} = HP_r \times \left[1 + \frac{2\Delta f}{f_0}\right] \longrightarrow (1)$$

Rate of change of kinetic Energy is,

$$\frac{dW_{ke}}{dt} = P_r H \times \frac{2}{f_0} \frac{d(\Delta f)}{dt} \longrightarrow (2).$$

As the frequency changes the motor load changes, the rate of change of load with respect to frequency is considered to be Constant.

$$\therefore \left(\frac{\delta P_D}{\delta f}\right) \Delta f = B \Delta f \longrightarrow (3)$$

where, $B = \frac{\delta P_D}{\delta f}$ is Constant

writing the power Balance equation is

$$\Delta P_G - \Delta P_D = \frac{2 P_r H}{f_0} \frac{\delta(\Delta t)}{\delta t} + B \Delta f$$

Dividing throughout by Pr

$$\Delta P_a(pu) - \Delta P_D(pu) = \frac{2H}{f_0}\frac{\delta(\Delta f)}{\delta t} + B\Delta f(pu) \quad \to (4)$$

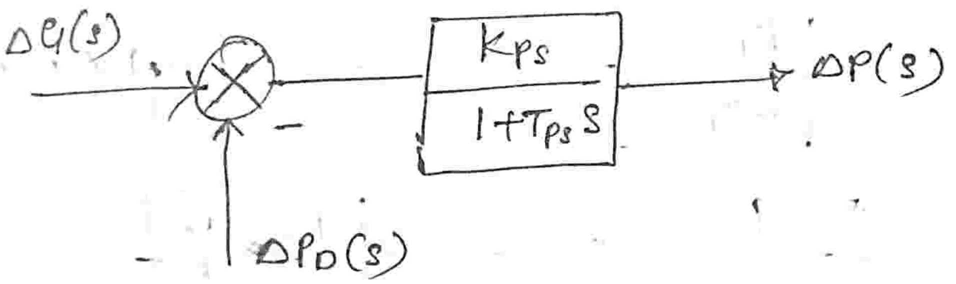
Taking Laplace transformation on both sides.

$$\Delta F(s) = \frac{\Delta P_a(pu)(s) - \Delta P_D(pu)(s)}{\frac{2H}{f_0} \times s + B}$$

$$\boxed{\Delta F(s) = \left[\Delta P_a(s) - \Delta P_D(s)\right] \times \left[\frac{K_{ps}}{1+T_{ps}}\right]}$$

where $T_{ps} = \frac{2H}{Bf_0}$ → power system time constant

$K_{ps} = \frac{1}{B}$ → power system gain.



10) Explain with neat diagram proportional plus integral controller.

A:- We know that due to change in load demand there is a droop in frequency vs load current.

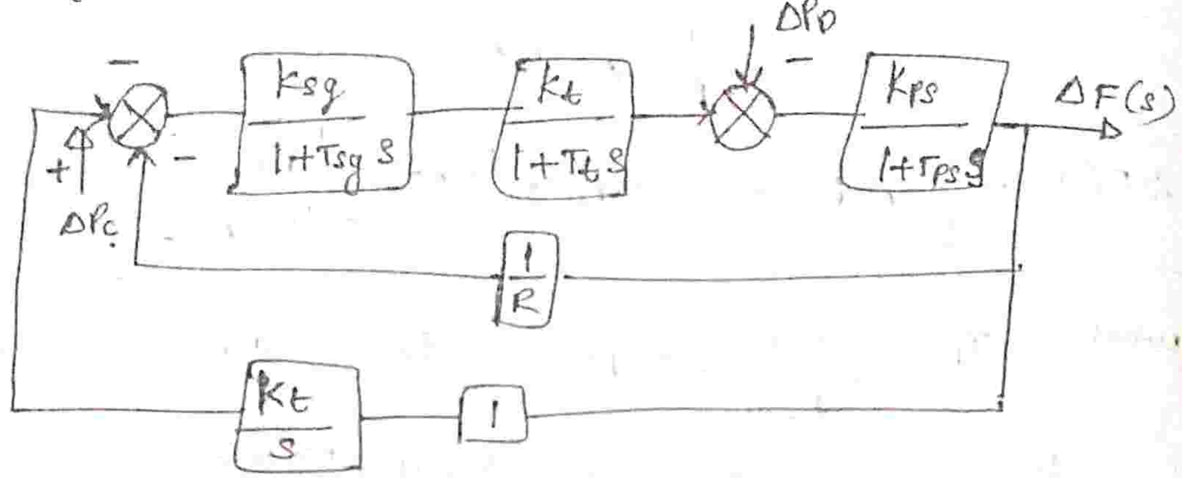
The change in frequency is not desirable for reliable operation of power system.

Hence a integral controller is used b/w speed changer settings and the frequency.

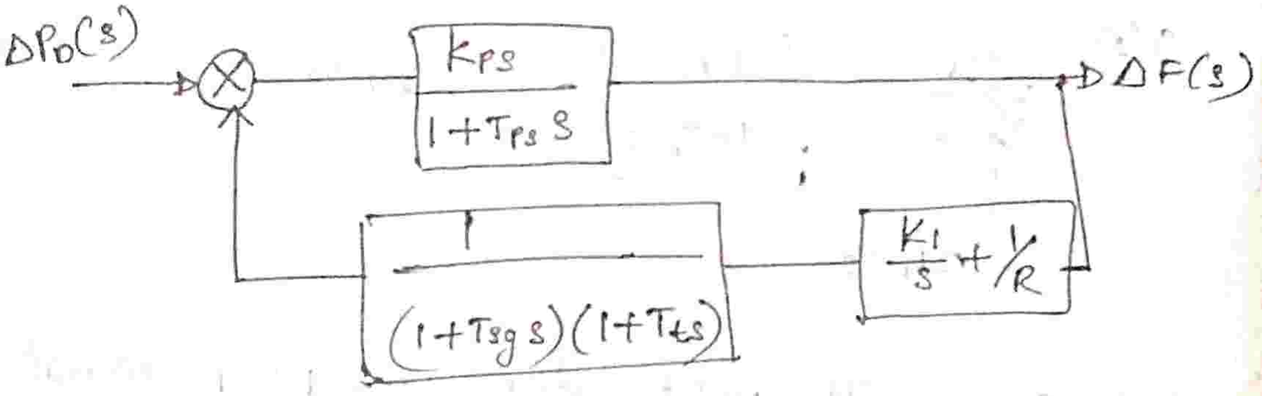
deviation from the output.

From control theory we know that the steady state error is zero for integral controller

This is achieved by constantly changing speed changer settings with variation in Load.



Assuming $K_{sg} K_t = 0$, $\Delta P_c = 0$



$$\Delta F(s) = \frac{-K_{ps}}{(1+T_{ps}s) + \frac{K_{ps}}{(1+T_{sg}s)(1+T_t s)} \times \left(\frac{K_I}{s} + 1/R\right)} \times \Delta P_D(s)$$

Under steady state,

$$\Delta P_D(s) = \frac{\Delta P_D}{s}$$

$$\Delta f = \lim_{s \to 0} s\,\Delta F(s) = 0$$

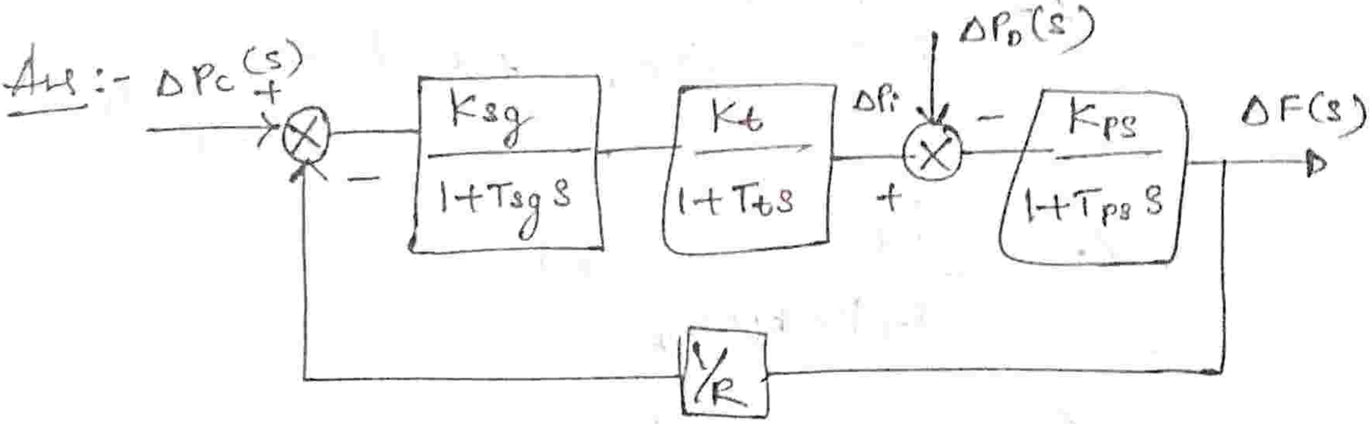
$$\Delta f = \lim_{s \to 0} s \times \frac{-K_{ps}}{(1+T_{ps}s) + \frac{K_{ps}}{(1+T_{sg}s)(1+T_{t}s)} \times \left(\frac{K_I}{s} + \frac{1}{R}\right)} \times \frac{\Delta P_D}{s}$$

$$\therefore \boxed{\Delta f = 0}$$

By the introduction of integral controller change in frequency will become zero under steady state.

11) Explain the steady state analysis of ALFC.

Ans:-



From above block diagram, there are two important incremental inputs to the load frequency control system

- ΔP_c → change in speed changer settings
- ΔP_D → change in load demand.

For such an operation the steady change in frequency for a sudden change in load demand

$$\Delta P_D(s) = \frac{\Delta P_D}{s}$$

from block diagram,

$$\Delta P_D(s) = \frac{\Delta P_D}{s}$$

$$\Delta F(s) = \frac{K_{ps}}{(1+T_{sg}s) + \frac{K_{sg}}{1+T_{sg}s} \times \frac{K_t}{1+T_{t}s} \times \frac{1}{R} \times K_{ps}}$$

find steady state frequency is obtained using final value theorem, Hence

$$\Delta f = \lim_{s \to 0} s\,\Delta F(s)$$

$$\Delta f = \lim_{s \to 0} s \times \frac{-K_{ps}}{(1+T_{ps}s) + \frac{K_{sg}K_{st}K_{ps}}{(1+T_{sg}s)(1+T_{ts})} \times 1/R} \times \frac{\Delta P_D}{s}$$

$$\Delta f = \frac{K_{ps}}{1+K_{sg}K_tK_{ps}/R} \times \Delta P_D$$

$$\Delta f = \frac{1}{B + 1/R} \Delta P_D$$

where, $B = \frac{1}{K_{ps}}$, $R \rightarrow$ speed regulation of governor.

Always B is very much less than $1/R$

$$\Delta f = -R\Delta P_D$$

$$B << 1/R$$

$$\Delta f = -R\Delta P_D$$

The droop of the load frequency curve is mainly determined by R.

Case 2 :-

change in speed changer setting with load demand remaining fixed

i.e., $\Delta P_D = 0$

$$\Delta F(s) = \frac{K_{sg} K_t K_{ps}}{(1+T_{sg}s)(1+T_t s)(1+T_{ps}s) + K_{sg}K_t K_{ps} \times 1/R} \times \Delta P_c(s)$$

$$\Delta F(s) = \frac{-K_{sg} K_t K_{ps}}{(1+T_{sg}s)(1+T_{ts}s)(1+T_{ps}) + K_{sg}K_t K_{ps} \times 1/R}$$

$$\Delta f = \lim_{s \to 0} s \Delta F(s)$$

$$= \frac{-K_{sg} K_t K_p}{1 + K_{sg} K_t K_{ps} \times 1/R}$$

let $K_{sg} K_t = 1$

$B = 1/K_{ps}$

$$\boxed{\Delta f = \frac{1}{B + 1/R}}$$