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Simulation and Analysis of Automatic Load Frequency Control Using PI Controller

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Abstract:*The preliminary role of an automatic load frequency control (ALFC) is to control the real power as well as frequency. The load on the power network is always changes with time, resulting in the change in frequency. The change in frequency is highly undesirable in power system and maximum permissible range of frequency is ±3%. One of the major requirement in system is to give reliable and quality operation in multi-area system. In interconnected large power system variation in frequency can lead to serious large-scale stability problem. Here to control the frequency variation, PI controller is used for both single as well as two area control system. In single and two areas, the simulation is done through with and without reheat system.*

Keywords—ALFC, single area, multi area, system stability, PI controller,PID controller,SRH,DRH.

I. INTRODUCTION

In a modern electrical power system an automatic generation control (AGC) is a system to adjust the output power of different generating units of different power stations in response to change in the load. In power system it is not possible to hold the frequency as well as voltage constant by manually control. Hence, automatic generation control units are required. As we know that frequency is depended on speed of generators which are rotated by their prime movers. In interconnected power system with two or more areas, the load frequency control has two main control loops. 1) primary control 2) secondary control. Primary control loops can be achieved by governing mechanism. in this loop, the frequency maintaining at the specific value cannot be successful. the second control loop is used to control the active power at the tie line between neighboring areas.

Frequency should be constant because in an interconnected power system loads are closely balanced movement by movement. This balance can be shown by measuring the system frequency. If frequency is increasing that means more power being generated, then used. In this situation all machines in the system are accelerating. Whereas if the frequency is decreasing which means a lot of load is drawn power then the generation. In this situation instantaneous generation can be provided. And also all generators are slowing down. In global, the maximum permissible change in frequency is ± 3%Hz only. In our India frequency deviation should be range between 48.5Hz to 51.5Hz.
When power system operates at lower frequency, it may affect the quality of power supply and it is not allowed. When frequency beyond their limits bellow effect may be occurring.
Excessive vibration in turbine due to that turbine blade may failures. When frequency below 48.5Hz the turbine control devices are fully open and this time the generating units are fully loaded. more and more decreasing in frequency reduces the efficiency of auxiliary devices like feed pumps (FD & ID). Generator exciters losses their speed hence generating emf will be decrease. Due to this, voltage droops occurs. At industrial side it will also effect on quality of product due to change in power frequency. It is because of some of the motors are depends upon the frequency. The electrical clocks are driven by synchronous motors. The accuracy of the clock is not only depending on the frequency but also is an integral of the frequency error.
The below frequency operation of the power transformer isn't fascinating. For constant system voltage, if the frequency below the desire level than the normal flux within the core will increase that is leads to low efficiency and overheating of the transformer windings.

1) Automatic Voltage and Frequency Control

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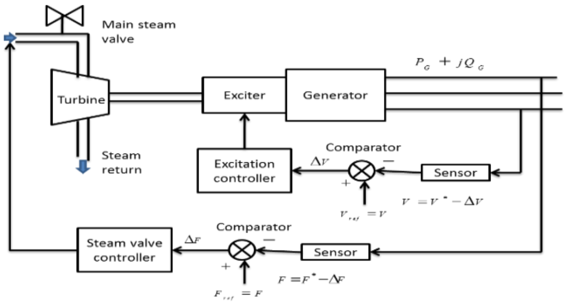

Fig.1 Voltage and frequency control

In power system network it is not possible to hold frequency as well as voltage constant by manually control. Hence, automatic control units are to be used in generating station. Suppose initially system is in a steady state condition that means system have constant terminal voltage, constant frequency and constant generating power. Here we focus only on change in frequency deviation. Suppose there is sudden change in load demand. In first case let consider that load demand is increase. Hence due to increase in load demand, at output side measure the frequency. It will decrease because our load demand is increase. Hence as shown in figure (1), sensor will sense the output frequency and send it to comparator. Comparator will compare that output frequency to the reference frequency. Now as output frequency is less than reference frequency, their deference is positive. After that comparator send it to the steam valve controller. As this deference is positive, steam valve controller sends positive signal to the main steam valve to open their position. So steam flow is increase and more power will be generated. Same will be understandable for decrease in load demand.

II. MATHEMATICAL SYSTEM MODELS

It is important to understand the mathematical models for governing system, load model, generation models, turbine models etc.

1) Speed governing system model

Equation:

$$\Delta X_5 = \left[\Delta P_c(s) - \frac{1}{D}\Delta F(s)\right] \times \frac{Kg}{1 + sTg}$$

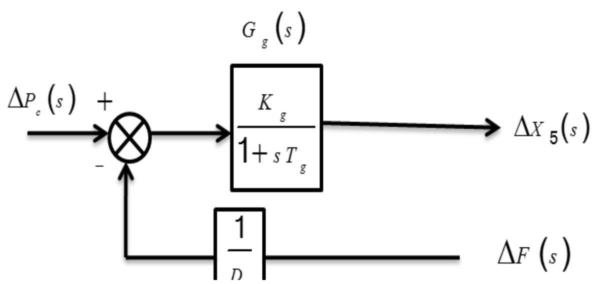

Fig.2 Speed governing model

2) Generator load model

Equation:

$$\Delta F_{(s)} = \left[\Delta P_{G(s)} - \Delta P_{D(s)}\right] \times \frac{K_P}{1 + sT_P}$$

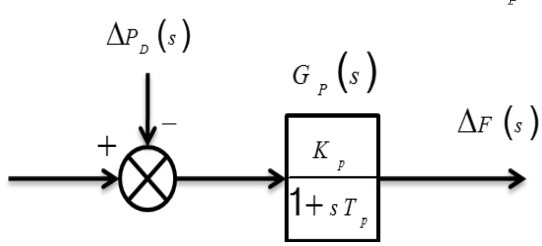

Fig.3 Generator load model

3) Turbine model

- There may be two types of turbine are used in steam power plant.

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a) Non Reheat steam turbine
Equation

$$G_{t(s)} = \frac{\Delta P_G(s)}{\Delta X_5(s)} = \frac{K_t}{1 + sT_t}$$

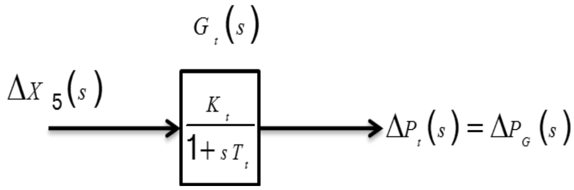

Fig.4 Non reheat system model

b) Reheat steam turbine

- There are two types of reheat turbine system.

i. Single reheat turbine system

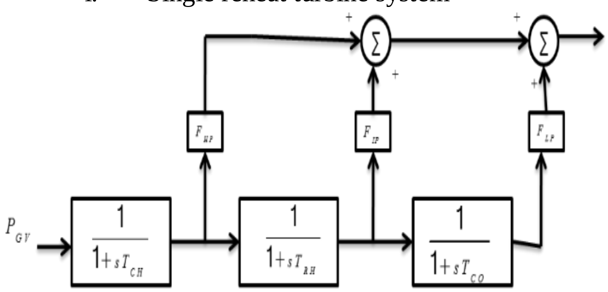

Fig.5 Single reheat turbine system model

ii. Double reheat turbine system

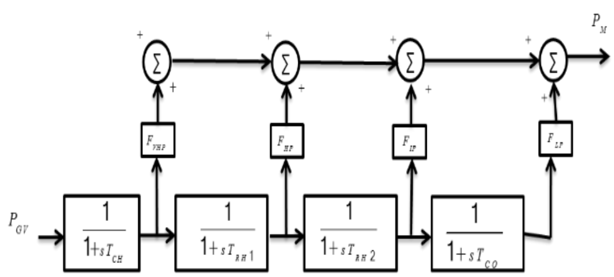

Fig.6 Double reheat turbine system model

4) Mathematical model for an isolated system

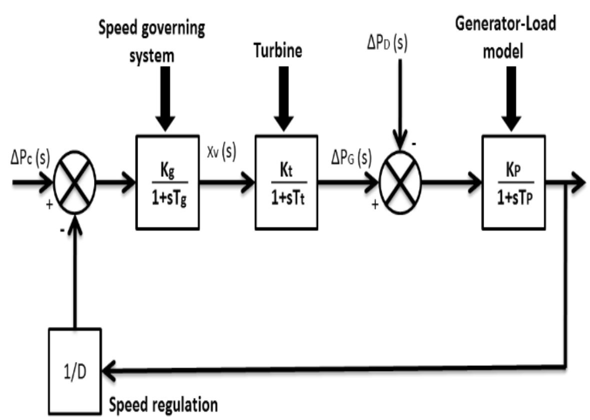

Fig.7 Mathematical model

Above figure is basic block diagram for an isolated system.

III SIMULATION AND RESULTS

i. MATLAB Simulation for single area system with and without PI controller

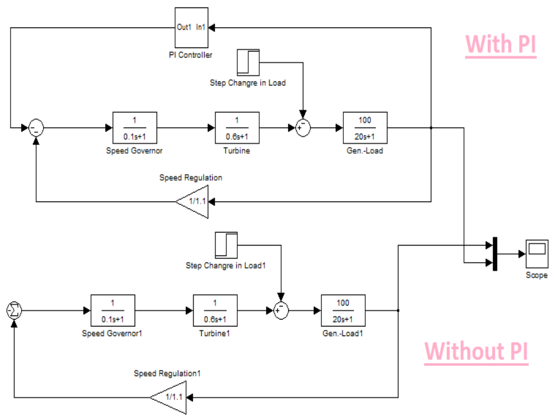

Fig.8 MATLAB simulation for single area system with and without PI controller

- **Result**

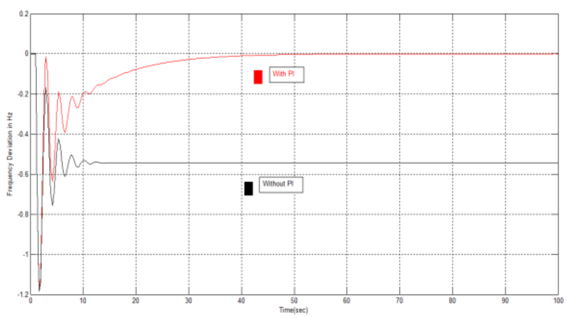

Fig.9 Result for single area with and without PI controller

- This simulation is done to reduce the steady state error in single area control system.

ii. MATLAB simulation for single area using non reheat and reheat system

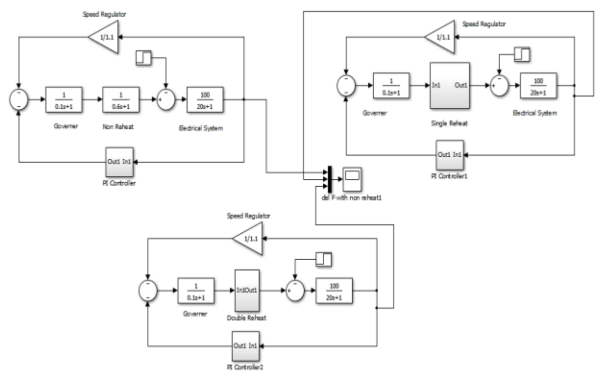

Fig.10 MATLAB simulation for single area using non reheat and reheat system

- **Result**
- We have demonstrated three different cases of different load changes.

- **Case-1: -** Normal condition (with 10% load change)

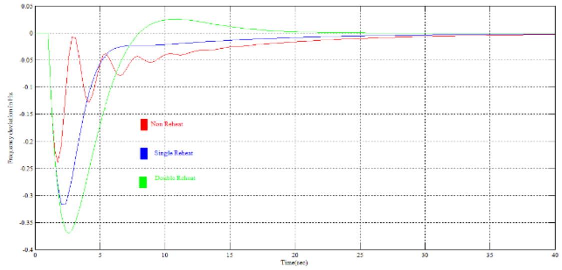

Fig.11 Result of single area with 10% load change

- **Case-2: -** Abnormal condition (with 20% load change)

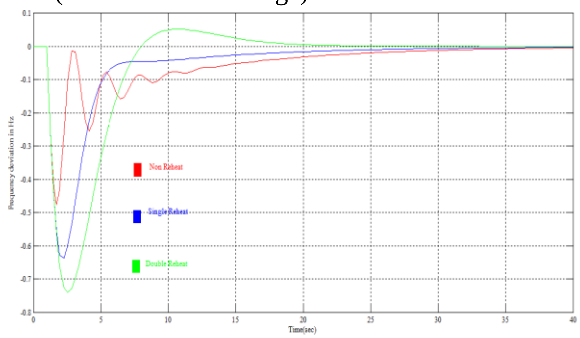

Fig.12 Result of single area with 20% load change

- **Case-3: -** Worst condition (with 50% load change)

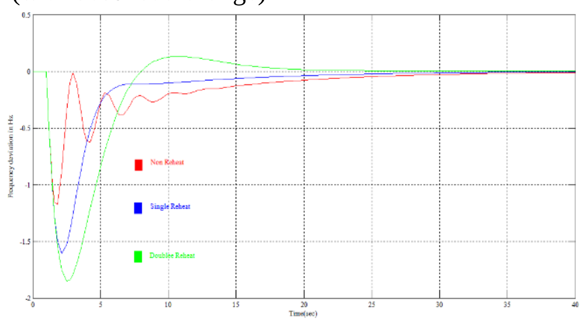

Fig.13 Result of single area with 50% load change

From the above 3 cases it is seen that if load is increase then frequency deviation is also increase. But in case of approximation (non-reheat) model it did not show actual deviation in the system while accurate (single or double) model show the actual deviation. This may result in case of non-reheat model frequency sense relay will not trip while for same parameter, single or double reheat model frequency sense relay will trip because maximum permissible frequency is ±3% (±1.5Hz).

iii. Parameter variation for single area

a) Varying governing time constant Tsg

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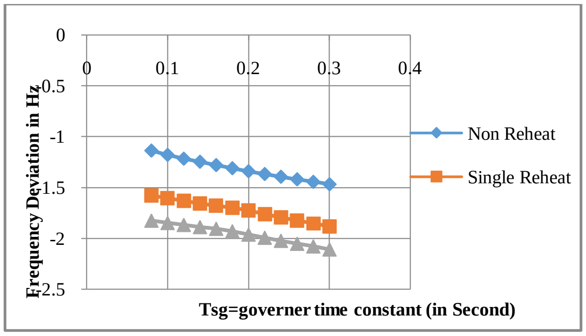
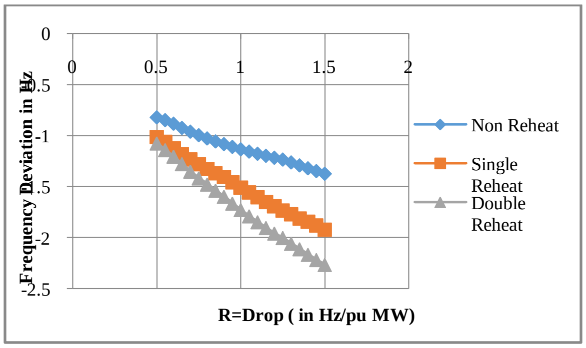


Varying governing time constant, in non-reheat model frequency deviation is not shown actual and its shown in permissible limit. But in single or double reheat model it's above the permissible limit which is actual deviation in system.

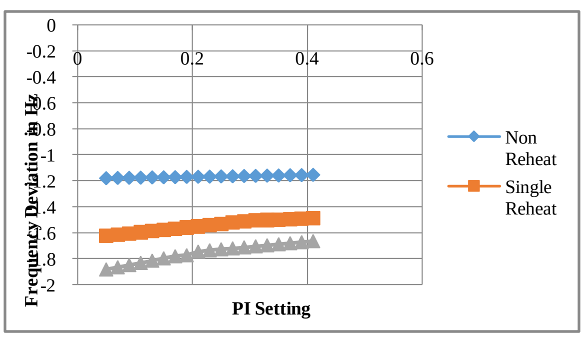
b) Varying droop R



Gradually increase in droop R, frequency deviation increase. But in non-reheat model, it will not show actual deviation. While single and double reheat model show actual deviation and it is more than permissible limit.

c) Varying PI controller setting

Varying in PI controller setting, for non-reheat model frequency almost constant and it is within in permissible limit. But in case of single and double reheat system, frequency is decrease but it is above permissible limit.



iv. Error pattern for single area control system

a) Error pattern for governor time constant

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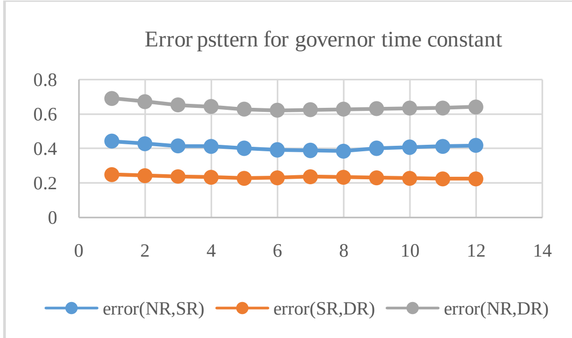
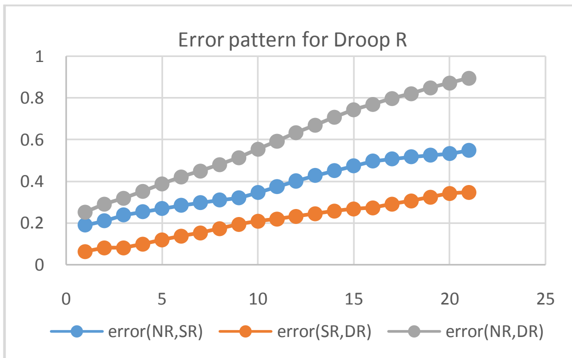


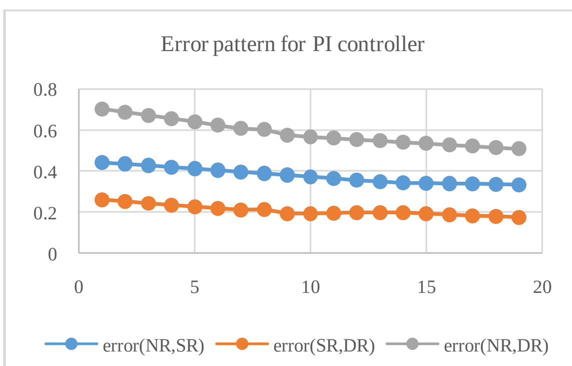
Error between non-reheat, single reheat and double reheat is almost constant. That means while change in governing time constant, frequency deviation is almost same for all three models.

b) Error pattern for droop R



Error between non-reheat, single reheat and double reheat is increase. Ratio of increasing in error is almost same for all models.

c) Error pattern for PI controller



From the above error pattern, the error between non-reheat, single reheat and double reheat is almost constant and also rate of change of PI setting is same for all models.

IV. <u>Conclusion</u>

It is concluded that from the above simulation we get constant frequency without steady state error and also elimination of approximation in prime-mover modeling. Power system stability can be maintained and accurate analysis can be achieved. Parameters for single as well as two area system can be adjusted. For wildly understanding, Eigen value analysis will be done to analyze the stability of power system in terms of frequency deviations.

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