Study of Two Area Load Frequency Control in Deregulated Power System

Isha Garg, Mohd. Ilyas

Abstract**: *In power system, any sudden load perturbations cause the deviation of tie- line exchanges and the frequency fluctuations. So, load frequency control (LFC) or automatic generation control (AGC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. In this paper, automatic generation control scheme is adopted in multi area deregulated power system.***

Index Terms**: Automatic generation control, deregulated power system, load frequency control, multi area control,.**

I. INTRODUCTION

Recently power system restructuring has been a worldwide trend with the introduction of competitive market system under deregulation. Also, major changes have been introduced into the structure of electric power utilities all around the world. The reason for this was to improve the efficiency in the operation of power system by means of deregulating the industry and opening it up to private competition. In this new frame work, consumers will have an opportunity to make a choice among competing providers of electric energy. The net effect of such changes will mean that the transmission generation and distribution systems must now adapt to a new set of rules dictated by open markets.

In power system, any sudden load perturbations cause the deviation of tie- line exchanges and the frequency fluctuations. So, load frequency control (LFC) or automatic generation control (AGC) is a very important issue in power system operation and control for supplying sufficient and reliable electric power with good quality. The main goal of AGC of a power system within specified tolerance is to maintain the frequency of each area and tie- line power flow by adjusting the MW outputs of AGC generators so as to accommodate fluctuating load demands [1]. Automatic generation control (AGC) in a multi-area interconnected power system has four principal objectives when operating in either the so-called normal or preventive operating states:

- Matching total system generation to total system load
- Regulating system electrical frequency error to zero
- Distributing system generation amongst control areas so
- that net area tie flows match net area tie flow schedules
- Distributing area generation amongst area generation sources so that area operating costs are minimized, subject to appropriate security and environmental constraints.

The first objective is conventionally associated with system primary or governor speed control; turbine speed governors respond proportionally to local frequency deviations and normally bring the rate-of change of frequency to zero within a time-frame of several seconds[2].

The latter three objectives are same accomplished by supplementary controls directed from area control centers. The second and third AGC objectives are classically associated with the regulation function or load-frequency control (LFC), while the forth objective is associated with the economic dispatch function of automatic generation control. The latter two functions typically operate in a time frame from several seconds to several minutes.

Power system loads and losses are sensitive to frequency. Data captured right after frequency disturbances indicate that their aggregate initial change is in the same direction as the frequency change. Once a generating unit is tripped or a block of load is added to the system, the power mismatch is initially compensated by an extraction of kinetic energy from system inertial storage which causes a declining system frequency. As frequency decreases, the power taken by load decreases. Equilibrium for large systems is often obtained when the frequency sensitive reduction of loads balances the output power of the tripped unit or that delivered to the added block of load at the resulting (new) frequency. If this effect halts the frequency decline it usually does so in less than 2 seconds. If the mismatch is large enough to cause the frequency to deviate beyond the governor dead band of generating units, their output will be increased by governor action. For such mismatches, an equilibrium is obtained when the reduction in the power taken by loads plus the increased generation due to governor action compensates for the mismatch. Such equilibrium is normally obtained within a dozen seconds after the tripping of a unit or connection of the additional load.

Typical speed droops for active governors are in the range of about 5%. (Governor Droop is the percent change in frequency which would cause the unit's generation to change by 100% of its capability.) This level of sensitivity to frequency allows many isolated systems, which are not necessarily small in capacity, to perform satisfactorily without AGC. Thus, at the expense of some frequency deviation, generation adjustment by governors provides ample opportunity for a follow up manual control of units. The objectives of the follow up control, especially under normal changes of load, are to return the frequency to the schedule,

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to minimize production cost, and to operate the system at an adequate level of security. The purpose of AGC is to replace portions of the above mentioned manual control. As it automatically responds to normal load changes, AGC reduces the response time to a minute or two, more or less.

II. TWO- AREA CONTROL

A "Two-area interconnection" is comprised of regions, or "areas", that are interconnected by tie-lines. Tie-lines have the benefit of providing inter-area support for abnormal conditions as well as transmission paths for contractual energy exchanges between the areas. The area boundaries are determined by tie-line metering for AGC and contractual billing purposes [3].

In an interconnection where AGC in more than one area is driven solely by a frequency signal, there will be large power oscillations between controlling areas unless regulating actions taken by all areas can be realized simultaneously. Further, the operation of such an interconnection would face a more severe problem if the areas attempting to control frequency had measurement error. An area that measured the frequency at a value higher than others would reduce its generation, while others raised, both attempting to force frequency (as they each measured it to the scheduled value.

On the surface, an alternative to frequency based control may seem to be that each area generate enough power to serve its internal loads and losses, plus the total scheduled power interchange 'Ts" with other areas. However, if every area operated with this objective, then for reasons described below the interconnection might not be able to operate satisfactorily [4].

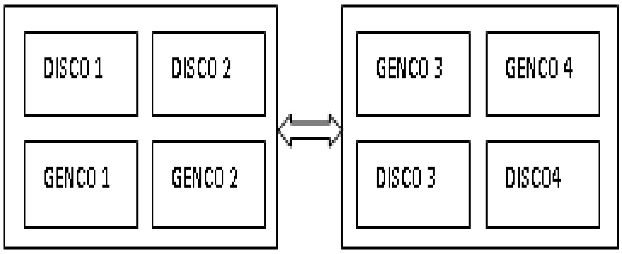
The difference between an area's generation and the power taken internally by loads and losses is the sum of power flows "Ta" on all tie-lines between this area and others. The scheme whereby each area controls its Ta to match its Ts is called constant net interchange (or flat tie-line) control. Consider a system comprising two areas, 1 and 2, and suppose area 1 measures its interchange several MW below the actual, and area 2 measures its own correctly. Then both areas will continuously raise their generation and no equilibrium can ever be reached. Alternately, assume area 1 uses an erroneous interchange schedule whose magnitude is higher than that used by area 2 for its purchase. The same instability occurs. Even in the absence of the above errors, this method of control is unable to provide satisfactory operation because it mulls in severely depressed frequency when either area is not able to produce its share of generation. As area 2 will attempt to maintain its interchange at the schedule, the system may collapse if a large unit is tripped in area 1. Just as it was found impossible, for reasons that are now obvious, for generators to operate stably in parallel without providing a suitable droop to their governor characteristics, so it was found impossible for systems to operate stably in padle1 under either constant frequency or constant net interchange control [2][5].

III. DEREGULATED POWER SYSTEM FOR LFC WITH TWO AREAS

In the competitive environment of power system, the vertically integrated utility (VIU) no longer exists. Deregulated system will consist of GENCOs, DISCOs, transmission companies (TRANSCOs) and independent system operator (ISO). However, the common AGC goals, i.e.restoring the frequency and the net interchanges to their desired values for each control area, still remain. The power system is assumed to contain two areas and each area includes two GENCOs and also two DISCOs as shown in Fig.1 and the block diagram of the generalized LFC scheme for a two area deregulated power system is shown in Fig. 2. A DISCO can contract individually with any GENCO for power and these transactions are made under the supervision of ISO.

To make the visualization of contracts easier, the concept of a "DISCO participation matrix" (DPM) will be used [2]. DPM is a matrix with the number of rows equal to the number of GENCOs and number of columns equal to number of DISCOs in the system. For the purpose of explanation, consider a two-area system in which each area has two GENCOs and two DISCOs in it. Let GENCO1,

GENCO 2, DISCO 1 and DISCO 2 are in area-1, and GENCO 3, GENCO 4, DISCO 3 and DISCO 4 are in area-2 as shown in figure 1.



AREA1 AREA2

Figure 1: two area power system

The DPM of above figure can be given as:
DPM=

	DISCO1	DISCO2	DISCO3	DISCO4
GENCO1	cpf 11	cpf 12	cpf 13	cpf 14
GENCO2	cpf 21	cpf 22	Cpf23	cpf 24
GENCO3	cpf 31	cpf 32	cpf 33	cpf 34
GENCO4	cpf 41	cpf 42	cpf 43	cpf 44

It can be thought of as a fraction of a total load contracted by a DISCO (column) toward a GENCO (row). Thus, the ij-th entry corresponds to the fraction of the total load power contracted by DISCO j from GENCO i. The sum of all the entries in a column in this matrix is unity. DPM shows the participation of a DISCO in a contract with a GENCO, and hence the "DISCO participation matrix".

cpf ij refers to "contract participation factor". For the purpose of explanation, suppose that DISCO 2 demands 0.1 pu MW power, out of which 0.02 pu MW is demanded from GENCO 1, 0.035 pu MW from GENCO 2, 0.025 pu MW demanded from GENCO3 and 0.02 pu MW demanded from GENCO 4.

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The column 2 entries can be easily defined as:
cpf 12= (0.02/0.1) = 0.20;
cpf 22=(0.035/0.1) = 0.35;
cpf 32= (0.025/0.1) = 0.25;

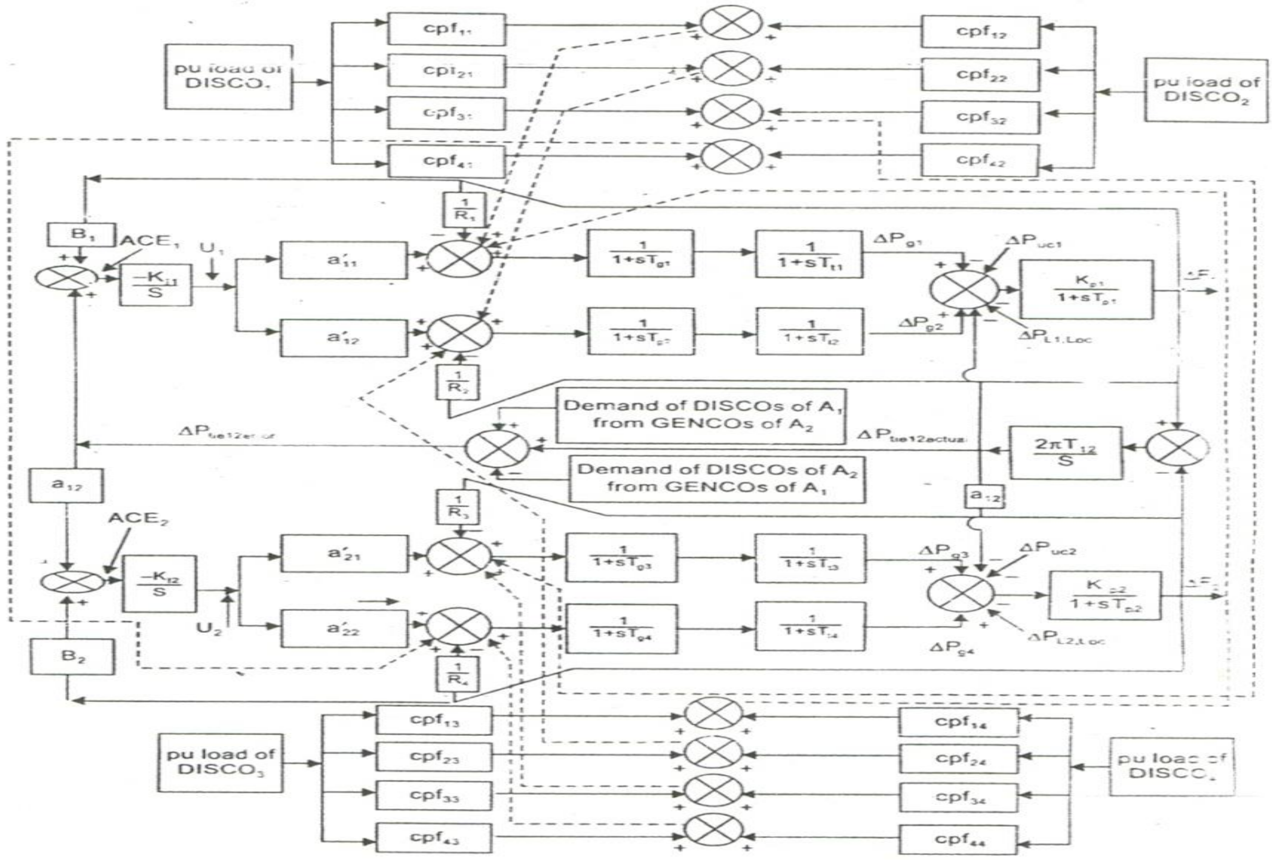

Figure 2: block diagram of two area deregulated power system

cpf 42 = (0.02/0.1) = 0.20;
also cpf 12+ cpf 22+ cpf 32+ cpf 42 = 1.0
other cpfs are defined easily to obtain the entire DPM. In general
∑i = cpf ij = 1.0

IV. BLOCK DIAGRAM REPRESENTATION

Now formulate the block diagram for a two area AGC system in the deregulated scenario. Whenever a load demanded by a DISCO changes, it is reflected as a local load in the area to which this DISCO belongs. This corresponds to the local loads ・PL1 and ・PL2 and should be reflected in the deregulated AGC system block diagram at the point of input to the power system block. As there are many GENCOs in each area, ACE signal has to be distributed among them in proportion to their participation in AGC. Coefficients that distribute ACE to several GENCOs are termed as " ACE participation factors".

Note that

$$\sum_{i=1}^{NGENCO_j} \alpha'_{ji} = 1.0$$

Where a'ji = participation factor of i-th GENCO in j-th area. NGENCOj = number of GENCO in j-th area

Unlike the traditional AGC system, a DISCO asks or demands a particular GENCO or GENCOs for load power. These demands must be reflected in the dynamics of the system. Turbine and governor units must respond to this power demand. Thus, as a particular set of GENCOs are supposed to follow the load demanded by a DISCO to particular GENCO specifying corresponding demands. The demands are specified by cpfs (elements of DPM) and the pu MW load of a DISCO. These signals carry information as to which GENCO has to follow a load demanded by which DISCO.

The scheduled steady state power flow on the tie-line is given as:

Scheduled ΔPtie12 = (Demand of DISCOs in area-2 from GENCOs in area-1) – (Demand of DISCOs in area-1 from GENCOs of area-2)

Scheduled ΔPtie12= ($\sum_{i=1}^{2} 1 \sum_{j=3}^{4} cpfij$ ΔPLj) – ($\sum_{i=3}^{4} 1 \sum_{j=1}^{2} cpfij$ΔPLj)

At any given time, the tie-line power error is defined as:

Error = Actual - Scheduled
ΔPtie12 = ΔPtie12 - ΔPtie12

The tie-line power error vanishes in the steady-state as the actual tie-line power flow reaches the scheduled power flow. This error signal is used to generate the respective ACE signals as in the traditional scenario:

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ACE1 = B1 Δ F1 + ΔPerror tie12s

ACE2 = B2 Δ F2 + α12ΔPerror tie12

For two area system contracted power supplied by i-th GENCO is given as:

For i=1

ΔP1= cpf11 ΔPL1+cpf12 ΔPL2+cpf13 ΔPL3 +cpf14 ΔPL4

Similarly, ΔP2, ΔP3, ΔP4 can easily be calculated.

In this closed loop model above ΔPuc1 and ΔPuc2 are non-contracted power demand (if any).

Also from this closed loop model ΔPL1, LOC = ΔPL1 + Δ PL2

and ΔPL2, LOC = ΔPL3 + ΔPL4

The inputs ΔPL1, LOC and ΔPL2, LOC in the closed loop model are part of the power system model, not part of AGC sarea AGC system in a deregulated environment is shown in figure 2.

V. CONCLUSION

In the proposed AGC implementation, contracted load is fed forward through the DPM matrix to GENCO set points i.e. ΔP1, ΔP2, ΔP3 and ΔP4 as shown in closed loop model.The actual loads affect system dynamics via the inputs ΔPL, LOC to the power system blocks. Any mismatch between actual and contracted demands will result in a frequency deviation that will result in a frequency deviation that will drive AGC to redispatch GENCOs according to ACE participation factors.

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