# GENERATION AUTOMATIC CONTROL

## FREQUENCY AUTOMATIC CONTROL

*GOVERNING SYSTEMS*

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# FREQUENCY AUTOMATIC CONTROL

*By Luiz Renato Gomes*

## 1. INTRODUCTION

Really power systems endeavor [make effort] to maintain frequency error within limits, so that synchronous electrical clock will be accurate.
This concernment has as objective to take some remarks about the frequency control applied to generation control of power systems.
There are lots of things that cause error in the automatic control. Time error is a great problem to power system control.
From now on we can make a question: How to calculate time error for a great power system as a 60-cycle electrical system?
Here we are going to do some observations and after that we are going to give two examples considering a great system.

## 2. FREQUENCY ERROR PROBLEM

We are going to suppose that we want to calculate time error of a 60-cycle system from frequency error given by the following expression:

$$\varepsilon_F(t) = \int_{to}^{tf} \Delta f(t)\, dt \tag{001}$$

This expression has the intentional action to associate with current frequency error the important condition of integrative-characteristic function that may cause the error function to an ordinary calculation based on the area error of the frequency shift.

Time displacement is given by the equation 002:

$$\Delta(t) = t_f - t_o \tag{002}$$

Here

$t_f$ final time computed from the error register
$t_o$ initial time computed from the error register

By assumption, the frequency deviation or shift was taken in a period of time given by equation 002 and this deviation can be an average value computed within it.

So we can write:

$$\Delta f(t) = \Delta f_{AV}$$

(003)

In equation 003 $\Delta f_{AV}$ is the average value of the frequency deviation.

So

$$\varepsilon_F(t) = \int_{to}^{tf} \Delta f(t)\, dt = \int_{to}^{tf} \Delta f_{AV}\, dt = \Delta f_{AV} \int_{to}^{tf} dt =$$

$$= \Delta f_{AV}\, [t_f - t_o] = \Delta f_{AV}\, \Delta t$$

$$\varepsilon_F(t) = \Delta f_{AV}\, \Delta t$$

(004)

Equation 004 represents and indicates the frequency error computed within a specific period of time. It is interesting to notice that the period of time can be chosen in terms of seconds, minutes, hours, and a lot more.
Other important remark is that the unit for equation 004 is Hz.s and represents frequency error considering a period of 1 second of computation.

## 3. TIME ERROR PROBLEM ASSOCIATE TO FREQUENCY ERROR

From frequency error, considering previous concernment, there is time error problem associated to it. Take into account that computing frequency error is given as a function of a constant average value it is possible to calculate time error.
If we need to compute frequency error within a specific period of time, considering, for instance, 1 hour of this computing, following relationship can be used to obtain error time associated from it.

So we have:
For $\Delta t$ = 1s

$$\varepsilon_{F/1\text{second}}(t) = \Delta f_{AV}$$

(005)

For $\Delta t$ = 60s

$$\varepsilon_{F/1\text{minute}}(t) = 60\ \Delta f_{AV}$$

(006)

For $\Delta t$ = 3600s

$$\varepsilon_{F/1\text{hour}}(t) = 3600\ \Delta f_{AV}$$

(007)

There is a strict relationship between frequency error and time error that is associated with that, it is enough by dividing frequency error by 60 Hz.

So we have dividing equation 007 by 60 Hz:

For $\Delta t$ = 1s

$$\varepsilon_{T/1\text{second}}(t) = \frac{1}{60}\ \Delta f_{AV}$$

(008)

For $\Delta t$ = 60s

$$\varepsilon_{T/1\text{minute}}(t) = \frac{60}{60}\ \Delta f_{AV} = \Delta f_{AV}$$

(009)

For $\Delta t$ = 3600s

$$\varepsilon_{T/1\text{hour}}(t) = \frac{3600}{60}\ \Delta f_{AV} = 60\Delta f_{AV}$$

(010)

We can notice that the unit of time error is [s/hour].

## 3. EXAMPLE NUMBER 1

Admit that a great 60-cycle power system has been operated, for a long time, with an average frequency at 59,99 Hz. Calculate time error for an hour of operation.

Solution:

We can use, directly, equation 010.

$$\varepsilon_{T/1hour}(t) = 60\ \Delta f_{AV}\ = 60(59.99 - 60) = -0.6$$

$$\varepsilon_{T/1hour}(t) = -0.6 \quad \text{s/hour}$$

Remark:
It is interesting to notice that the computation for time error, although admensional, can be avaluable as a part of a unit that represents a specific time error value in seconds per period of time computed within the chosen register, in our case in 1 hour.

## 4. EXAMPLE NUMBER 2

How much time does a great 60-cycle system, with a 0.05-cycle frequency offset error, need to correct a 1-second time error?

Solution:

Considering formulas expressed in equations 005, 006 and 007, by using a specific period of time "m", we have by applying, directly:

$$\varepsilon_{F/\mathrm{m}\,(\mathrm{seconds})}(t) = m\ \Delta f_{AV} \tag{011}$$

Formula 011 can be taken as a generalization of equations 005, 006 and 007. We only have to get value to parameter "m".

If we take "m" as a period of time in seconds it is possible to develop the following concernment:

$$\varepsilon_{F/m\,(\mathrm{seconds})}(t) = m\ \Delta f_{AV}$$

To convert frequency error into time error, we have to divide previous equation by 60 Hz, and then:

$$\varepsilon_{T/m\,(\text{seconds})}(t) = \frac{\varepsilon_{F/m\,(\text{seconds})}(t)}{60} = \frac{m\,\Delta f_{AV}}{60}$$

Rearranging previous equation for isolating parameter "m", we have:

$$\frac{m}{60} = \frac{\varepsilon_{T/m\,(\text{seconds})}(t)}{\Delta f_{AV}}$$

By substituting given values:

$$\frac{m}{60} = \frac{1}{0.05} = 20 \quad \therefore \quad m = 1200\text{ s}$$

Remark:

We can notice that parameter "m" is given in seconds and its value is 1200 seconds or 20 minutes or 1/3 hours depending on the unit of it.

So we conclude that at 0.05-cycle frequency-error average value, a great 60-cycle electrical system last [hold out] about 20 minutes to correct 1-second time error.

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