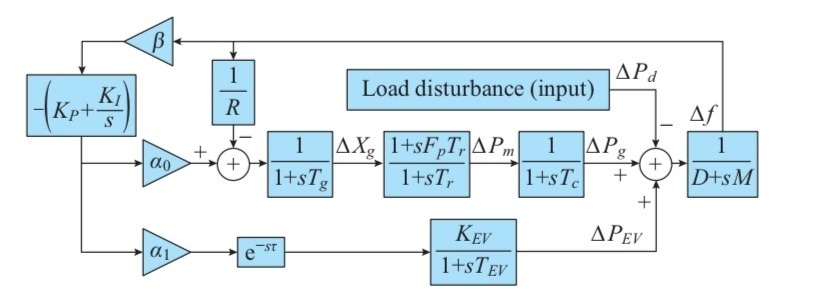
**COMPUTATION OF STABILITY DELAY MARGINS**

System model of single-area LFC with EV aggregator:



**G1**

+

**H1**

**G1**

**1**

**H2**

Let us consider,

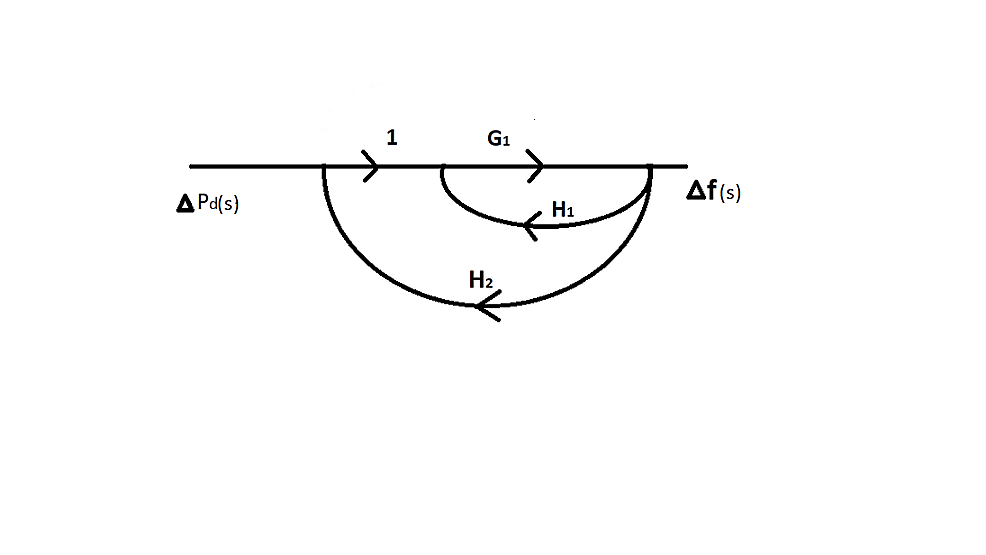
M=8.8 ; D=1 ;=

; ;

; ; ;

;

By using **signal flow graph method**, we find the transfer function of the System model of single-area LFC with EV aggregator.



.

**Maison’s Gain formula:**

Transfer function = .

=

=

**=**

The closed loop transfer function of the time-delayed load frequency control system relates **Δf(s)**, the incremental frequency variable (output variable) to load disturbance variable **Δ(s)** (input variable).

The closed loop transfer function is derived as follows:

G

**N(s) =+++++**

**=** [[ + + [ + + [ ++ +**s** [R]

**P(s) = + + + +**

**= ++** + **+ +**

**Q(s) = ++++**

= **+ + + +**

For stability region and delay margin computations, it is necessary to obtain the characteristic equation of the single area LFC-EV system.

The characteristic equation of the single area LFC-EV system:

**)**

**) + .**

The roots of the characteristic equation are:

**+ + + + 1.145 = 0**

**S = - 9.90431**

**S = - 5.36025**

**S = - 2.84345**

**S = - 0.221403**

**S = - 0.0923932 0.765317i**

The necessary condition for the single-area LFC-EV system to be asymptotically stable is that all the roots must be in the left half of the s-plane. In consideration of the single delay, the delay margin computation can be done by finding values of τ\* for which has roots on the jω-axis. For some finite value of τ\*, the characteristic polynomial of Δ (s, τ\*) =0 has a root on the imaginary axis at s= j, the equation of Δ (-s, τ\*) =0 will also have the same root on the imaginary axis for the same value of τ\* and due to the complex conjugate symmetry of complex roots. That means s=jωc will be a common root of the following equation:

**) =0**

By eliminating the exponential terms between the above two sub-equations, the following augmented polynomial is obtained:

) = P ( P (

**P(s)** =

**P(-s)** = .

**P(s)P(-s)** = + +++ .

**P(s)P(-s)** =(((( (

**Q(s)**  = .

**Q(s)** = .

**Q(s)Q(-s)**=

**Q(s)Q(-s) =**()

.

Substitute **s = j**

**P(j)P(-j)- Q(j)Q(-j) =** )+(+(+ (- -(- -) +- -

By substituting the polynomials of P( P(and into the augmented polynomial ) of can be represented as

W(.

2

+ 2– .

.

+ .

.

= 0.05765 ; 0.003323

= ; 0.62764 0.4510

2.33573 ; 12.6955

= ; 69.828

= 0.2290 ; -40.217

= -5.470

= 0.78661

**W () = 0**

**W () =** +0.451+12.6955­ - 5.47+0.786615=0

= −103.77

= −28.3095

= −8.06205

= −0.184679

**= 0.091843**

**= 0.606242**

The real positive roots are  **= 0.3030561** and **= 0.7786154.** Calculating the delay margin for each positive root and the minimum of those is taken as the system delay margin .

**=arctan(.**

Where = ; = ;

= ;

= –;

= – ;

= + ;

= - ;

= - + ;

= - - ;

= - ;

= ;

=

= 0.05765 ;

= ; 0.62764

2.33573 .

= .

= 0.2290 .

=

=

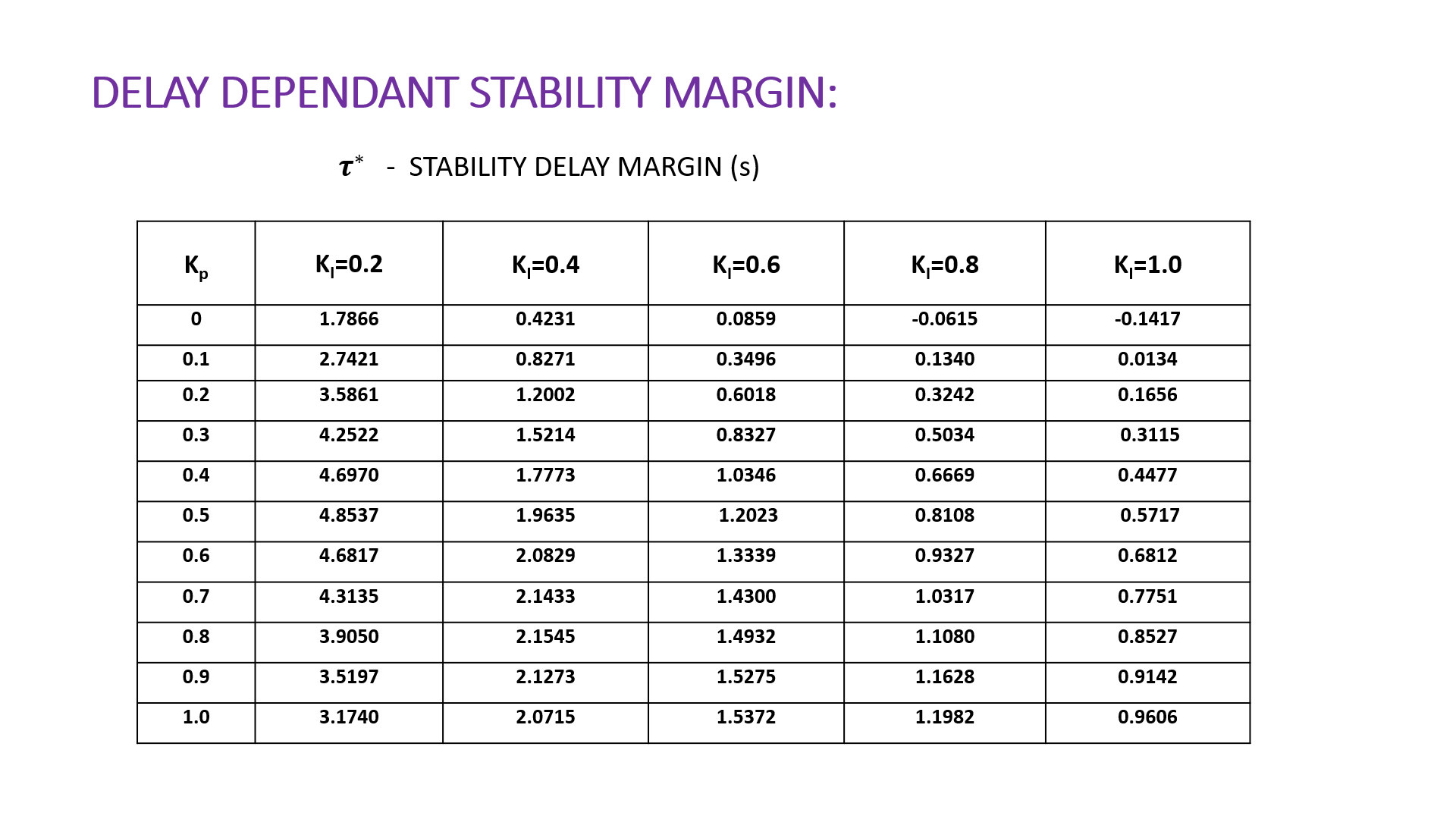
= 0.3030561.

= 0.7786154.

The stability delay margin for given ; ; ; = 0.3030561.

**DELAY DEPENDANT STABILITY MARGIN:**

- STABILITY DELAY MARGIN (s)



|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Kp** | **KI=0.2** | **KI=0.4** | **KI=0.6** | **KI=0.8** | **KI=1.0** |
| **0** | **1.7866** | **0.4231** | **0.0859** | **-0.0615** | **-0.1417** |
| **0.1** | **2.7421** | **0.8271** | **0.3496** | **0.1340** | **0.0134** |
| **0.2** | **3.5861** | **1.2002** | **0.6018** | **0.3242** | **0.1656** |
| **0.3** | **4.2522** | **1.5214** | **0.8327** | **0.5034** | **0.3115** |
| **0.4** | **4.6970** | **1.7773** | **1.0346** | **0.6669** | **0.4477** |
| **0.5** | **4.8537** | **1.9635** | **1.2023** | **0.8108** | **0.5717** |
| **0.6** | **4.6817** | **2.0829** | **1.3339** | **0.9327** | **0.6812** |
| **0.7** | **4.3135** | **2.1433** | **1.4300** | **1.0317** | **0.7751** |
| **0.8** | **3.9050** | **2.1545** | **1.4932** | **1.1080** | **0.8527** |
| **0.9** | **3.5197** | **2.1273** | **1.5275** | **1.1628** | **0.9142** |
| **1.0** | **3.1740** | **2.0715** | **1.5372** | **1.1982** | **0.9606** |