EC 2255 - CONTROL SYSTEM

UNIT I- CONTROL SYSTEM MODELING

1. What is meant by a system?

It is an arrangement of physical components related in such a manner as to form an entire unit.

2. List the two types of control systems?

The two types of control system are, open loop systems and closed loop system.

3.What is an open loop system?

The control system in which the output has no effect upon the input quantity, is known as open loop control system.

4. Define manually controlled systems?

Systems that involve continuous manual control by a human operator are called manually controlled system.

5. What is a closed loop system?

A system in which output has some effect upon the input quantity, in such a manner as to maintain the desired output value.

6. What is feedback?

The feedback is a control action, in which the output is sampled and a proportional signal is given to input for automatic correction of any changes in desired output.

7. Give the types of feedback?

Negative feedback
Positive feedback.

8. What type of feedback is employed in control system?

Negative type of feedback is employed in control system.

9. When will feedback exist in a system?

Feedback is said to exist in a system, when a closed sequence, of cause and effect relations exist between system available.

10. Define transfer function

Transfer function of a given system is defined as the ratio of the laplace transform of output variable to laplace transform of input variables at zero input conditions.

11. Define order of the system.

The highest power of the complex variables in the denominator of the transfer function determines the order of the system.

12. Give the advantages of open loop system.

The advantages of open loop system are

1. Such systems are simple in construction.
2. Very much convenient when input is difficult to measure.
3. Such systems are easy for maintenance point of view.
4. Generally these are not troubled with problems of stability.
5. Such systems are simple to design and hence economical.

13. Give the disadvantages of open loop system.

The disadvantages of open loop system are

1. Such systems are inaccurate and unreliable because accuracy of such systems are totally dependent on the accurate precalibration of the controller.
2. Such systems give inaccurate results if there are variations in the external environment i.e. Systems cannot sense environmental changes.
3. Similarly they cannot sense internal disturbances in the system, after the controller stage.

14. Give the advantages of closed loop system.

The advantages of closed loop system are:

1. Accuracy of such system is always very high because controller modifies and manipulates the actuating signal such that error in the system will be zero.
2. Such systems senses environmental changes, as well as internal disturbances and accordingly modifies the error.
3. In such system, there is reduced effect of non-linearites and distortions

15. Compare open loop system and closed loop system.

Open loop	Closed loop
1.Innaccurate	Accurate
2.Simple and economical	Complex and costlier
3.The changes in output due to external disturbance are not corrected	The changes in output due to external disturbances are corrected automatically
4.They are generally stable	Great efforts are needed to design a stable system

16 .Mention the basic elements of closed loop system

Command input, reference transducer, error detector, controller, process to be controlled, feedback element

17. Give the important features of feedback.

- Reduced effects of non-linearities and distortion.
- Increased accuracy.
- Reduced sensitivity of the ratio of the output to input to variations in system characteristics.
- Tendency toward oscillation or instability.

18. What are the basic elements used for modeling mechanical translational system?

The model of mechanical translational system can be obtained by using three basic elements mass spring and dashpot.

19. Name the two types of electrical analogous for mechanical system.

The two types of analogies for mechanical system are force-voltage analogy and force-current analogy.

20. What is block diagram?

A block diagram of a system is a pictorial representation of the functions performed by each component of the system and shows the flow of signals.

21. What are the basic components of block diagram?

The basic components of block diagram are block, branch point, summing point, arrows.

22. What is signal flow graph?

The graphical representation of the variables of a set of linear algebraic equations representing the system is called signal flow graph.

23. Give the properties of signal flow graph?

- The signal in the system flows along the branches and along the arrows associated with the branches.

- The value of variable represented by any node is an algebraic sum of all the signals entering at the node.
- The signals gets multiplied by the branch gain or branch transmittance when it travels along it.
- Applicable only to linear time invariant systems.

24. Define chain node.

A node having incoming and outgoing branches is known as chain node.

25. Define self loop.

A feedback loop consisting of only one node is called self loop.

26. Define Loop gain.

The product of all the gains of the branches forming a loop is called loop gain.

27. Define forward path.

A path from the input to output node is defined as forward path.

28. List the advantages and disadvantages of feedback systems.

- Increased accuracy.
- Reduced sensitivity.
- Reduced effects of non-linearities and distortion
- Increased bandwidth.
- Tendency towards oscillation or instability

UNIT II – TIME RESPONSE ANALYSIS

1. What are the standard test signals employed for time domain studies?

The standard test signals employed for time domain studies are 1. step signal, ramp signal, parabolic signal, impulse signal.

2. What are time domain specifications?

The time domain specifications are 1. Delay time, 2. Rise time, 3. Peak time, 4. Maximum peak overshoot, 5. settling time.

3. What is the difference between type and order of a system?

Type number of a system indicates the number of poles at the origin whereas the order of the system indicates the **order** of the differential equation governing the dynamics of a system. (or highest degree of denominator polynomial of the transfer function.

4. Define settling time.

Settling time is defined as the time taken by the response to reach and stay with in a specified tolerance band of its final value.

5. Define peak overshoot.

It is defined as the difference between the peak value of step response and the steady output.

6. What is time response?

The time response is the output of a closed loop system as a function of a time. It is denoted by c(t). it is given by the inverse Laplace transform of the product of input and transfer function of a system.

7. What is transient response.

The output variation during the time, it takes to achieve its final value is known as transient response. The time required to achieve the final value is called transient response.

8. What is steady state response?

It is that part of the time response which remains after complete transient response vanishes from the system output.

9. Define step signal.

It is the sudden application of the input at a specified time.
Mathematically it can be expressed as R(t) = A for t > 0
R(t) = 0 for t< 0. If A= 1,then it is called unit step function denoted by u(t)

10. Define ramp signal.

It is the constant rate of change in input. i.e. gradual application of the input.
Magnitude of ramp input is nothing but its slope. Mathematically it can be expressed as
R(t) = At for t > 0 ,R(t) = 0 for t< 0. If A= 1,then it is called unit ramp function.

11. Define parabolic signal.

It is a signal, in which the instantaneous value varies as square of time from an initial value of zero at t =0.Mathematically it can be expressed as $R(t) = A t^2/2$for t > 0 ,R(t) = 0 for t< 0. If A= 1,then it is called unit parabolic function

12. State various time domain specifications.

The time domain specifications are:

- Delay time.
- Rise time.
- Settling time.
- Maximum over shoot.
- Peak time.

13. How the system is classified n the basis of damping?

Depending on the value of damping, the system is classified into four cases:

- Case 1: Undamped system, (damping ratio = 0)
- Case 2: under damped system (0<damping ratio <1)
- Case 3: Critically damped system((damping ratio = 1)
- Case 4: Over damped system (damping ratio > 1)

14. Define damping ratio.

The damping ratio is defined as the ratio of actual damping to critical damping

15. Define steady state error.

The difference between the desired output and the actual output of the system is called steady state error, which is indicates the accuracy and plays an important role in designing the system.

16. What is positional error coefficient?

Steady state error of the system for a step input is 1/(1+ Kp). where Kp is the positional error coefficient. The positional error coefficient is given by

$$Kp = \lim_{s \to 0} G(S)H(S)$$

17. What is velocity error coefficient?

Steady state error of the system for a ramp input is 1/(Kv). where Kv is the velocity error coefficient. The velocity error coefficient is given by $Kv = \lim_{s \to 0} SG(S)H(S)$

18. What is acceleration error coefficient?

Steady state error of the system for a step input is 1/(Ka). where Ka is the acceleration error coefficient. The acceleration error coefficient is given by $Ka = \lim_{s \to 0} S^2 G(S)H(S)$

19. How are control systems classified in accordance with the number of integrations in the open loop transfer function?

Control systems are classified in accordance with the number of integrations in the open-loop transfer function as

- Type - 0 system.
- Type – 1 system.
- Type - 2 system.

20. What is the order of the system?

The order of the system is given by the order of the differential equation, governing the system. It is also given by the maximum power of S in the denominator polynomial of the transfer function. The maximum power of S also gives number of poles of the system and so the order of the system is also given by number of poles of the transfer function.

21. What is called a proportional plus integral controller?

In an integral error compensation scheme, the output response depends in some manner upon the integral of the actuating which produces an output signal of two terms, one proportional to the actuating signal and the other proportional to tits integral. Such a controller is called proportional plus integral controller.

22. What is called a PID controller?

To increase the damping factor of the dominant poles of a PI controlled system, it is combined with a derivative error scheme. Such a controller is called a PID controller.

23. What is the advantage of PD controller?

The advantage of PD controller is that as the damping increases due to compensation, with n remaining fixed, the system settling time reduces.

24. What is the effect of PD controller on the system performance?

The effect of PD controller is to increase the damping ratio of the system and so peak overshoot is reduced.

25. What is the effect of PI controller on the system performance?

The PI controller is increases the order of the system by one, which results in reducing the steady state error. But the system becomes less stable than the original system.

26. Why derivative controller is not used alone in control systems?

The derivative controller produces a control action based on the rate of change of error signal, and it does not produce corrective measures for any constant error. Hence derivative controller is not used alone in the control system.

UNIT –III FREQUENCY RESPONSE ANALYSIS

1. Define cut-off rate.

The slope of the resultant magnitude curve near the cut-off frequency is called cut-off rate.

2. Define resonant peak(Mr)

It is the maximum value of magnitude of the closed loop frequency response. Larger the value of the resonant peak, more is the value of the peak overshoot of system for step input. It is a measure of relative stability of the system.

3. Define gain-cross over frequency. (ωgc).

The frequency at which magnitude of $G(j\omega)H(j\omega)$ is unity. I.e. 1 is called gain cross over frequency.

4. Define phase-cross over frequency. (ωgc).

The frequency at which phase angle of $G(j\omega)H(j\omega)$ is -180°. is called phase cross over frequency.

5. Define gain margin G.M. in bode plot.

In root locus gain K is increased, the system stability reduces and for a certain value of K, it becomes marginally stable. (Except first and second order systems). So gain margin is defined as the margin in gain allowable by which gain can be increased till system on the verge of instability.

6. Define phase margin.

Phase margin is similar to the gain, it is possible to introduce phase lag in the system. I.e. negative angles without affecting magnitude plot of $G(j\omega)H(j\omega)$. The amount of additional phase lag, which can be introduced in the system till the system reaches on the verge of instability is called phase margin P.M.

7. How the gain margin and phase margin be improved?

The easiest way to improve G.M. and P.M. is to reduce the gain. However this increases steady state error and makes the system sluggish. Better methods are available. These methods are adding compensating networks are compensators.

8. Define bandwidth.

It is defined as the range of frequencies over which the system will respond satisfactorily. It can also be defined as range of frequencies in which the magnitude response is also flat in nature. So it is defined as range of frequencies over the magnitude of closed loop response. i.e $c(j\omega))/R(j)\omega$ does not drop by more than 3db. From its zero frequency value.

9. List the advantages of bode plots.

- Transfer function of system can be obtained from bode plot.
- Data for constructing complicated polar and nyquist plots can be easily obtained from bode plot.
- It indicates how system should be compensated to get desired response.
- Relative stability of system can be studied by calculating G.M. and P.M. from bode plot.

10. What is meant by the term corner frequency?

The frequency at which change of slope from 0 db to –20db occurs is called corner frequency, denoted by ωc . $\omega c = (1/T)$ hence asymptotic i.e. approximate magnitude plot for such factor is 0 db line up to $\omega c = (1/T)$ and line of slope –20 db /dec. when ω $> \omega c$ i.e. above $\omega c = (1/T)$

11. What is meant by frequency response of system?

The magnitude and phase relationship between the sinusoidal input and the steady state output of a system is termed as the frequency response. In linear time invarient systems, the frequency response is independent of the amplitude and phase of the input signal.

12. List the frequency domain methods to find the stability of the system.

The commonly used frequency domain methods to sketch the frequency response of the systems are

- Bode plot
- Polar plot
- Nyquist plot
- Nichol's chart

13. What are frequency domain specifications?

The frequency domain specification indicates the performance of the system in frequency domain. And they are

- Resonant peak
- Cut-off rate
- Resonant frequency
- Gain margin
- Phase margin

14. What are the advantages of frequency response analysis?

- Without the knowledge of the transfer function, the frequency response of stable open-loop system can be obtained experimentally.
- For difficult cases, such as conditionally stable systems, nyquist plot is probably the only method to analyze stability.
- Frequency response can be precisely applied to the systems those do not have rational transfer function. I.e. e-TS etc.
- It can be extended to certain non-linear systems.

  The apparatus required for obtaining frequency response is simple and inexpensive and Easy to use.

15. What is bode plot?

The transfer function is represented as a lograthimic plot which consists of two graphs, one giving the logarithm of G(j ω) both plotted against frequency in logarithm scale. These plots are called bode plots.

16. What is a polar plot?

The sinusoidal transfer function G(j ω) = Re[G(j ω)] + jIm[G(j ω)]

G(j ω) = G(j ω) < G(j ω) = M< ø

From the above equations it is seen that G(j ω)may be represented as a phasor of magnitude M and phase angle ø. As the input frequency ω is varied from 0 to α, the magnitude M and phase angle ø change and hence the tip of the phasor G(j ω) trace a locus in the complex plane. The locus thus obtained is known as polar plot.

17. What is Nichol's chart?

Nichols transformed the constant M and N circles to log magnitude and the phase angle coordinates and the resulting chart is known as Nichols chart. The Nichols chart consists of M and N superimposed on ordinary paths.

18. What are the M and N circles?

The magnitude, M of the closed loop transfer function section with unity feedback will be in the form of circles in complex plane for each constant value of M. The family of these circles are called M circles.

Let N= tanα where α is the phase of closed loop transfer function with unity feed back. For each constant of N, a circle can be drawn in the complex plane the family of these circles are called N circles.

19. What are compensators?

In control systems design, under certain circumstances it is necessary to introduce some kind of corrective subsystems to force the chosen plant to meet the given specifications. These subsystems are known as compensators and their job is to compensate for the deficiency in the performance of the plant.

20. What are the two methods of specifying the performance of control system?

By a set of specifications in time domain or in frequency domain such as peak overshoot, setting time, gain margin, phase margin, steady state error etc.

By optimality of certain function e.g. en internal function.

21. What are the two types of compensation techniques write short notes on them?

i. Cascade or series compensation.

ii. Feedback compensation.

In cascade or series, the compensator transfer function is placed in cascade with the plant transfer function. In feedback compensation, the compensator is placed in the feedback path.

22. List the types of compensation.

- Series Compensation
- Parallel compensation
- Series-parallel compensation

23. What is meant by compensation?

All the control systems are designed to achieve specific objectives. The certain requirements are defined for the control system. If a system is to be redesigned so as to meet the required specifications, it is necessary to alter the system by adding an external device to it. Such a redesign of a system using an additional device is called compensation.

24. What is series compensation?

The compensator is a physical device whose transfer function is denoted as Ge(s). If the compensator is placed in series with the forward path transfer function of the plant, the scheme is called series compensation.

25. What is parallel compensation?

Introduced in such a feedback path to provide an additional feedback loop. Such compensation is called feedback or parallel compensation.

26. What is series-parallel compensation?

In some cases, it is necessary to provide both types of compensation, series as well as feedback. Such a scheme is called series-parallel compensation

UNIT-IV STABILITY ANALYSIS

1. Define parameter variations.

The parameters of any control system cannot be constant through its entire life. There are always changes in the parameters due to environmental changes and other disturbances. These changes are called parameter variations.

2. Define sensitivity of a control system.

An effect in the system performance due to parameter variations can be studied mathematically defining the tern sensitivity of a control system. The change in particular variable due to parameter can be expressed in terms of sensitivity.

3. State Routh's criterion for stability.

Routh's criterion states that, the necessary and sufficient condition for the stability is that, all the elements in the first column of the **Routh's array** be positive. If the condition is not met, the system is unstable, and the number of sign changes in the elements of the first column of **Routh's array** corresponds to the number of roots of characteristic equation in the right half of the S-plane.

4. What are the conditions for a linear time invariant system to be stable?

A linear time- invariant system is stable if the following two notions of system stability are satisfied.

- When the system is by a bounded input, the output is bounded.
- In the absence of the input, the output tends towards zero irrespective of initial conditions.

5. What do you mean by asymptotic stability?

In the absence of the input, the output tends towards zero (the equilibrium state of the systems) irrespective of initial conditions. This stability is known as asymptotic stability.

6. How the system is classified based on stability?

Based on the stability, the system can be classified as

- Absolute stable system.
- Conditionally stable system.
- Unstable system.
- Marginally stable or critically stable system.

7. Define BIBO stability.

A linear relaxed system is said to have BIBO stability if every bounded (finite) input results in a bounded (finite) output.

8. What is the necessary condition for stability?

The necessary condition for the stability is that all the co-efficient of the characteristic polynomial be positive.

9. State Hurwitz criterion.

The necessary and sufficient conditions to have all roots of the characteristic equation in left half of the s-plane is that, the sub-determinants DK, k = 1,2,…..,m obtained from Hurwitz's determinant must be positive.

10. Define absolute stable.

Absolutely stable with respect to a parameter of the system, if it is stable for all values of this parameter.

11. What do you mean by relative stability?

Relative stability is a quantitative of how fast the transients die out in the system. If it is stable for all values of this parameter.

12. What is ROUTH stability criterion?

ROUTH stability criterion states that, the necessary and sufficient condtition for stability is that all of the elements in the first column of the routh's array be positive. If this condition is not met, then the system is unstable, and the number of sign changes in the elements of the first column corresponds to the number of roots of characteristic equation in the right half of the S-plane.

13. What do you mean by root locus technique?

Root locus technique provides a graphical method of plotting the locus of the roots in the S-plane as a given system parameter, is varied over the complete range of values(may be from zero to infinity). The roots corresponding to a particular value of the sysstem parameter can then be located on the locus or the value of the parameter for a desired root location can be determined from the locus.

14. What is centroid? How the centroid is calculated?

The meeting point of asymptotes with real axis is called centroid. The centroid is given by

Centroid (σ) = sum of real parts of poles – sum of real parts of zeros / P-Z

Where P= number of poles,Z = number of zeros.

15. What are asymptotes? Give the formula to calculate the angle of asymptotoes.

Asymptotes are straight lines, which are parallel to root locus going to infinity and meet the root locus at infinity. Angle of asymptoes = $+(2q+1)\ 180^0$ / P-Z, where P- no. of poles, Z-no.of zeros

16**. What are breakaway points?**

Points at which multiple roots of the characteristic equation occur are called breakaway points. A breakaway point may involve two or more than two branches.

17. What is angle criterion of root locus?

The angle criterion of root locus states that S =Sa will be a point on root locus if for that value of S, the argument or phase of G(S)H(S) is equal to an odd multiple of 180^0

18. What is dominant pole?

The dominant pole is a pair of complex conjugate pole which decides transient response of the system. In higher order systems, the dominant poles are very close to origin and all other poles of the system are widely separated and so they have less effect on transient response of the system.

19. How will you find the gain K at a point on the root locus?

The gain K at a point S= Sa on root locus is given by
K= product of length of vectors from open loop zero to the point Sa /
product of length of vectors from open loop poles to the point Sa

20. Define gain margin in Nyquist plot.

Gain margin is the amount of gain in decibels(db) that is allowed to be increased in the loop before the closed loop system reaches stability.

21. Define phase margin in Nyquist plot.

Phase margin may be defined as the angle in degrees through which the $G(j\omega)H(j\omega)$ plot must rotate about origin in order that the gain cross over point on the locus passes through the point (-1+j0)

UNIT-V **STATE VARIABLE ANALYSIS AND DIGITAL CONTROL SYSTEM**

1. What is state?

The state of dynamic system is defined as a minimal set of variables such that the knowledge of these variables at t =to together with the knowledge of inputs t > 0 completely determine the behavior of the system for t > to.

2. What is state variable?

The variables involved in determining the state of dynamic system are called state variables. Generally x1(t),x2(t),x3(t)…….xn(t) are called state variables.

3. What is state vector?

The state vector x(t) is the vector sum of all the state variables.

4. What is state space?

The space whose coordinate axes are nothing but the 'n' state variables with time as the implicit variable is called state space.

5. What is the condition to be satisfied for a sampled data system to be stable?

The poles of the pulse transfer function H(z) must lie inside z-plane unit circle.

6. What is the characteristic equation of a sampled data system?

The denominator polynomial of a closed loop pulse transfer function H(z) is known as the characteristic equation.

7. What is controllability?

A general nth order multi-input linear time invariant system

.

X = AX +Bu. Is completely controllable if and only if the rank of the composite matrix
Qc = [B:AB : A^2B:…….. :$A^{n-1}B$] is n

8. What is observability?

A general nth order multi-input multiple output linear time invariant system

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X = AX +Bu. , Y= CX is completely observable if rank of the composite matrix
Qc = [C^T:A^TC^T:…….. :$(A^T)^{n-1}B$] is n

9. List the methods used to test the stability of discrete time system.

- Jury's stability test.
- Bilinear transformation.
- Root locus technique.

10. Define sampled data system.

In a control system, if the signals in any part/point of the system is discrete (digital or sampled) then the entire system is said to be sampled data system.

11. When a control system can be called as sampled data control system?

Any control system can be called as sampled data control system, when ever,

- A digital system (computer/ microprocessor/microcontroller) becomes part of control system.
- Control components are on the time sharing mode.
- Control signals are discrete or digital signals.

12. Distinguish between sampled data systems and continuous-time systems.

Control system components of sampled data control system are able to handle discrete (digital) signals. On the other hand, continuous time system components can handle analog signals. Similarly output signals of sampled data system components are discrete (digital) signals.

13. What is digital controller?

A digital device used to generate control signal for which error signal is given as input.

14. What is quantization?

The process of approximating a discrete time continuous valued signal into a discrete valued signal is called quantization. If the sampled analog value lies in between two digital adjacent values then the sampled analog value will be represented by a digital value which is nearer to the analog value than the other. This process of approximation is called quantization.

15. What is coding?

Representation of sampled data by n bit binary number is called coding.

16. What is hold circuit?

A device used to convert digital signal into analog signal.

17. What is zero-order hold?

It is a hold circuit. The output of the hold circuit is analog signal whose magnitude equal to latest sampled value till next sample occurs.

18. What is first order hold?

The output of the first order hold is constructed from latest two samples (current and previous samples). The slope of the output signal is determined by this current and previous sample.

19. What is acquisition time?

Time taken by an analog to digital converter to sample the signal, to quantize it and to code it is known as acquisition time.

20. Define aperture time.

It is the duration of sampling of analog signal.

21. What is hold mode droop?

There is no droop in an ideal hold circuit. The change in signal magnitude during hold mode of a hold circuit is called hold mode droop.

22. What are the problems that may occur in a practical hold circuit?

- Hold mode droop may occur.
- Nonlinear variation during sampling aperture.
- Error in the periodicity of sampling.

23. How the high frequency noise in the output hold circuits can be filtered?

The control system components act as low pass filter. Hence the high frequency signals are automatically filtered.