

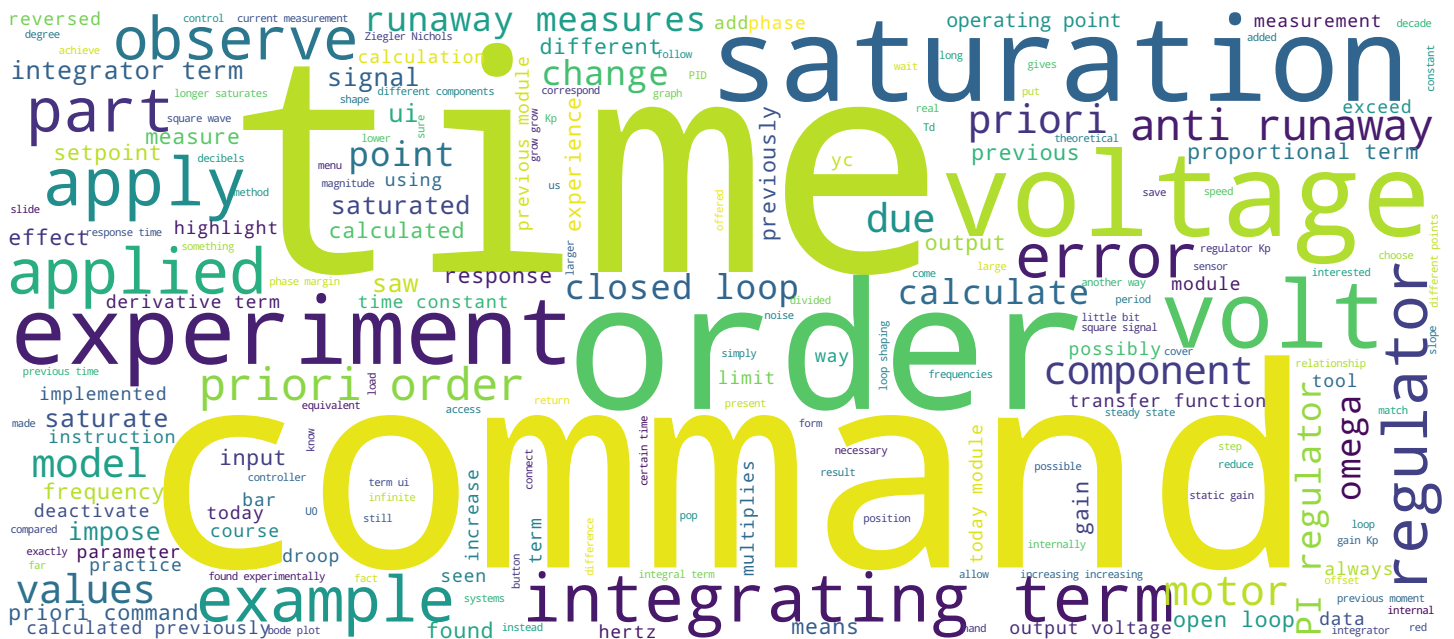
Synthèse du régulateur

Commande a priori et mesures anti-emballement

Controls Systems' Hand on Sessions

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Automatic Control Lab



Search MOOC



Video



- Commande a priori (feed-forward command)
 - Trouver expérimentalement la commande a priori
 - Calculer la commande a priori
 - Appliquer une commande a priori
- Mesures anti-emballement (Anti-Reset Windup)
 - PI sans ARW
 - Effet des mesures ARW
- Expériences

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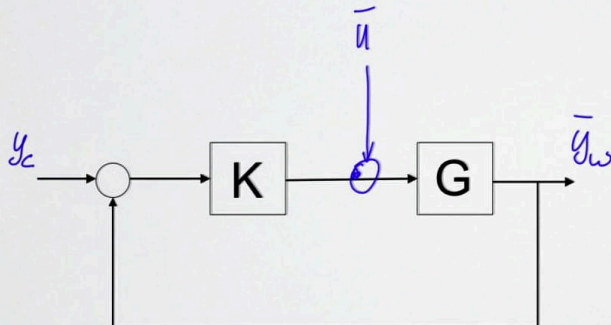
Bonjour. In today's module we will cover two points. First, the a priori order, which serves to impose an operating point, and secondly, anti-runaway measures which make it possible to saturate the value of the integrating term. We will see how to calculate this order a priori and also how to find it experimentally. Likewise, for anti-runaway measures, we will see the integration and saturation problems when using a PI regulator, then we will do some experiments to highlight these different points.

Notes

Summary



0m 04s



- Permet d'imposer un point de fonctionnement, par exemple dans la zone linéaire
- \bar{u} entraîne la vitesse de rotation \bar{y}_ω

$$\bar{u} = \frac{1}{\gamma_\omega} \bar{y}_\omega$$

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An a priori command makes it possible to impose an operating point, for example, in the linear region of our system. This a priori order is calculated as follows: it must match the voltage that is applied to my system to have a desired output which corresponds to the voltage that would be generated by my regulator for a given setpoint value. So my command is applied here, the \bar{u} command and I have the relationship between \bar{u} and \bar{y} which is given by this equation. My a priori open loop command is a command that is equivalent to the command to have y_ω equal to y_c in closed loop. This a priori order does not take into account possible disturbances.

Notes

Summary



0m 35s

Expérimentation 1 – Commande a priori



- Calculez la commande a priori U_0 avec le gain statique trouvé précédemment pour avoir $y_\omega = 2.5$ [v]
- Comparez cette valeur avec la valeur de U_0 trouvée expérimentalement en augmentant U_0 jusqu'à ce que le disque de rotation tourne à une vitesse y_ω de 2.5[v]. L'expérience se déroule en boucle **fermée** avec $K_p = 0$, T_i et T_d désactivés

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In this first experiment, you will calculate the order a priori with the values you found in the previous module to have an output voltage y_ω equal to 2.5 volts. Next, you will compare the calculated a priori value with the a priori order found experimentally. To do this, you will increase the U_0 value of your system until the output value of your system y_ω is equal to 2.5. To do this, you will put yourself in a closed loop, but you will impose the value of the regulator K_p equal to 0, that is to say that the K_p will be inactive. Likewise, T_i and T_d will be disabled.

Notes

Summary



1m 27s

Expérimentation 2 – PI & commande a priori



En utilisant le régulateur PI calculé précédemment (M2)

- Appliquez un signal carré avec Amplitude: 1[v], Offset: 1.5[v]
- Désactivez le terme intégral
- Observez le statisme
- Appliquez la commande a priori U_0 trouvée précédemment (pour 2.5[v])
- Observez le statisme, il est absent pour une valeur de consigne $y_c = 2.5[v]$ mais présent pour $y_c = 0.5[v]$

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In this experience, you will visualize the effect of the command a priori. To do this, you will use the PI regulator that you calculated in the previous module. You will then apply in a closed loop a 1 volt amplitude square signal with an offset of 1.5 volts, a frequency of 0.1 hertz. You will deactivate the integral term and you will observe the droop. Then you will apply the command a priori that you calculated previously for an output voltage of 2.5 volts, then you will observe the droop. It should be absent for a voltage of 2.5 volts, but present for a voltage of 0.5 volts.

Notes

Summary

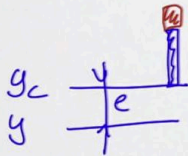


2m 10s

Effet du terme intégrateur

$$u = u_p + u_d + \underline{u_i} + u_0$$

$$u_{i_k} = u_{i_{(k-1)}} + K_p \frac{1}{T_i} \left(\frac{e(k) + e(k-1)}{2} \right) \cdot h$$



- Le terme intégrateur u_i du régulateur PID intègre l'erreur
- Par défaut, il n'y a pas de limite sur la valeur que peut prendre le terme intégrateur

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The command which is applied to the motor, it is the sum of the different components of this order, and there is for example a part which is due to the proportional term, a part which is due to the derivative term, a part which is due to the integrator term and possibly an a priori command u_0 . The regulator is implemented in the form of a computer program and we will be interested in the calculation of u_i . The calculation of u_i at the given time k , it is equal to the value of u_i at the previous moment plus the gain K_p which multiplies 1 on the time constant which multiplies the error at time k plus the error at the previous time k minus 1 divided by 2, all times the sample period. If I now look graphically at a u command for a PI regulator, I will have the following graph. If here, I have my set value, here I have the current measurement of the system, the difference between the two is my mistake and I will try to calculate the u for my PI regulator at a given time. I'm going to have a first part initially the previous value of the regulator is 0 and I only have this part which gives me, for example, this part in red.

Notes

Summary



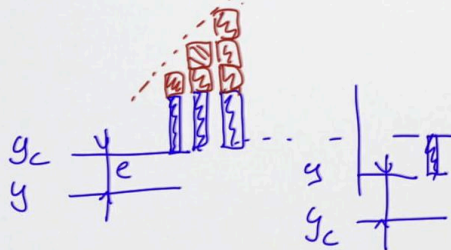
2m 53s

Effet du terme intégrateur

$$u = u_p + u_d + \underline{u_i} + u_o$$

$$u_{i_k} = u_{i_{(k-1)}} + K_p \frac{1}{T_i} \left(\frac{e(k) + e(k-1)}{2} \right) h$$

5 V



- Le terme intégrateur u_i du régulateur PID intègre l'erreur
- Par défaut, il n'y a pas de limite sur la valeur que peut prendre le terme intégrateur

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At the next moment, if the error is constant, I will have the same component for the proportional term and for the integrating term, this time I will have the previous value which is found here, plus something that was added for the current time. And so on proportional integrator. And what do we see here? It's that my system will grow, grow, grow, and here, the voltage U , which is the sum of these two values, will go on increasing, increasing, increasing, until I get out of my slide. This internal value is theoretical, can increase infinitely, but we saw that in practice, the system was saturated. Typically, in our example, we had an order which was, for example, saturated at 5 volts. So far there is no problem, the system will go up to the saturation value and stay like that. In any case, it will not be able to exceed the saturation value. The problem arises if there is, for example, a change of setpoint. The instruction will change sign. We will always have here y and here y_c . So the error will become the opposite of the previous value. If we now look at the component which is due to the proportional term, it will be reversed as the error was reversed.

Notes

Summary

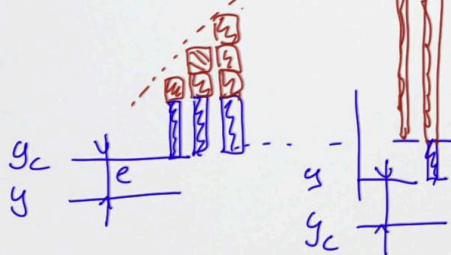


4m 37s

Effet du terme intégrateur

$$u = u_p + u_d + \underline{u_i} + u_o$$

$$u_{i_k} = u_{i_{(k-1)}} + K_p \frac{1}{T_i} \left(\frac{e(k) + e(k-1)}{2} \right) \cdot h$$



- Le terme intégrateur u_i du régulateur PID intègre l'erreur
- Par défaut, il n'y a pas de limite sur la valeur que peut prendre le terme intégrateur

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On the other hand, the component which is due to the integrating term, it will be worth that which is in the previous time, which will be worth approximately this value, minus a little bit, this means that we will have a component here which remains very, very large, larger than the saturation value. It has decreased a little, but it is still very large. The sum of these two values is the voltage that is applied to the motor. We see from this graph that we will have to wait a certain time so that the integrator term becomes empty and is lower than the saturation value.

Notes

Summary



6m 12s

Expérimentation 3 – PI effet du terme intégrateur



En utilisant le régulateur PI calculé précédemment

- Appliquez un signal carré d'amplitude ~ 3.8 [V] avec une fréquence de 0.1 [Hz]
- Observez le temps de réponse du système lors du changement de la valeur de consigne
- Au besoin, changez l'échelle des Y pour voir l'ampleur que peut prendre le terme intégrateur U_i

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In this experiment, you will highlight the problems of an integrating term which is not saturated. So you are going to use the regulator that you calculated previously, and you will apply a square wave amplitude of 3.8 volts with a frequency of 0.1 hertz. With such values, you will saturate the command. To see the effects of an integrating term that is not saturated, you will observe the system response when you have a change in the instruction. If necessary, you will change the scale Y_s in your user interface using the pop-up menu. Thus, you will be able to see the great amplitude what can the term integrator take?

Notes

Summary

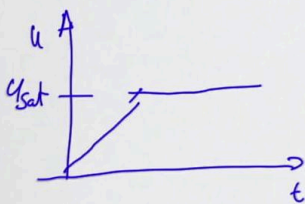


6m 50s

$$u = u_p + u_d + \underline{u_i} + u_o$$

$$\text{Si } u > u_{\text{sat}}$$

$$u_{i(k)} = u_{i(k-1)}$$



$$u_{i(k)} = u_{\text{sat}} - (u_p + u_d)$$

- Les mesures anti-emballement (ARW) saturer la valeur que peut prendre le terme intégrateur u_i
- Ces mesures sont activées uniquement lorsque la commande est saturée
- La saturation du terme intégrateur a pour effet de réduire le temps nécessaire à sa "vidange"

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The command that is applied to the motor is the sum of the different components for the proportional term, the derivative term, the integrator term and possibly an a priori order. We see that the term which poses a problem to us, it is the integrating term because it accumulates the error. And a very simple test to limit this value, that is to say that if my order u is larger than my saturation control, for example, here, the one we found in our system was 5 volts, then the value u_i of k , instead of being the value that the algorithm calculates, it is equal to the value found at the previous moment. And thus, there is saturation of the integrative term. If we look at this, as long as this measure is not applied, we have here in time, if I return to the drawing previously, here, my u order, we could see that my u order was increasing, and here, once my u exceeds my saturation u , my order is stuck at the saturation value and internally, my term u_i of k cannot take an infinite value, but is limited. There are other ways to saturate the term u_i , another way that we sometimes find in literature, this means that the value u_i of k , it is equal to the saturated u -value, so your saturation value, minus the sum of all other components up plus u_d . The one that is implemented in the systems you access, it's this value here.

Notes

Summary



Expérimentation 4 – Mesures anti-emballement



En utilisant le régulateur PI calculé précédemment

- Appliquez un signal carré d'amplitude $\sim 3.4[V]$ avec une fréquence de $0.1 [Hz]$
- Activez les mesures anti-emballement (ARW)
- Observez le temps de réponse du système lors du changement de la valeur de consigne
- Réduisez l'amplitude du signal carré jusqu'à ce que la commande ne sature plus
- Désactivez les mesures anti-emballement (ARW)
- Observez le temps de réponse du système

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In this experiment, you will repeat the same experience than previously, but this time you will activate anti-runaway or ARW measures to achieve this wind-up. This time you will observe the response time of the system when there is a change of setpoint. Once you have this experience, you will reduce the amplitude of the signal that you apply to your system until the command no longer saturates and once you are sure that the command no longer saturates, you will deactivate the anti-runaway measures and you will again observe the system response time.

Notes

Summary



9m 29s

Conclusions

Qu'ai-je appris aujourd'hui ?

- Une commande a priori permet d'imposer un point de fonctionnement
- Les mesures anti-emballement (ARW)aturent la valeur du terme intégrateur
- Dans la pratique, il est judicieux d'ajouter des mesures anti-emballement (ARW) dès que vous avez un régulateur avec terme intégrateur

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In today's module we saw how to calculate an a priori command to impose an operating point. We compared this result to an a priori order which was found experimentally, similarly, we have seen the potentially harmful effects of an integrating term if it is not saturated. To limit these effects, we have offered you anti-runaway measures which saturate the value of the integrating term. It should be noted that in practice it is always wise to add anti-runaway measures as soon as you add an integrator term to your regulator.

Notes

Summary



10m 04s