Wroclaw University of science and technology

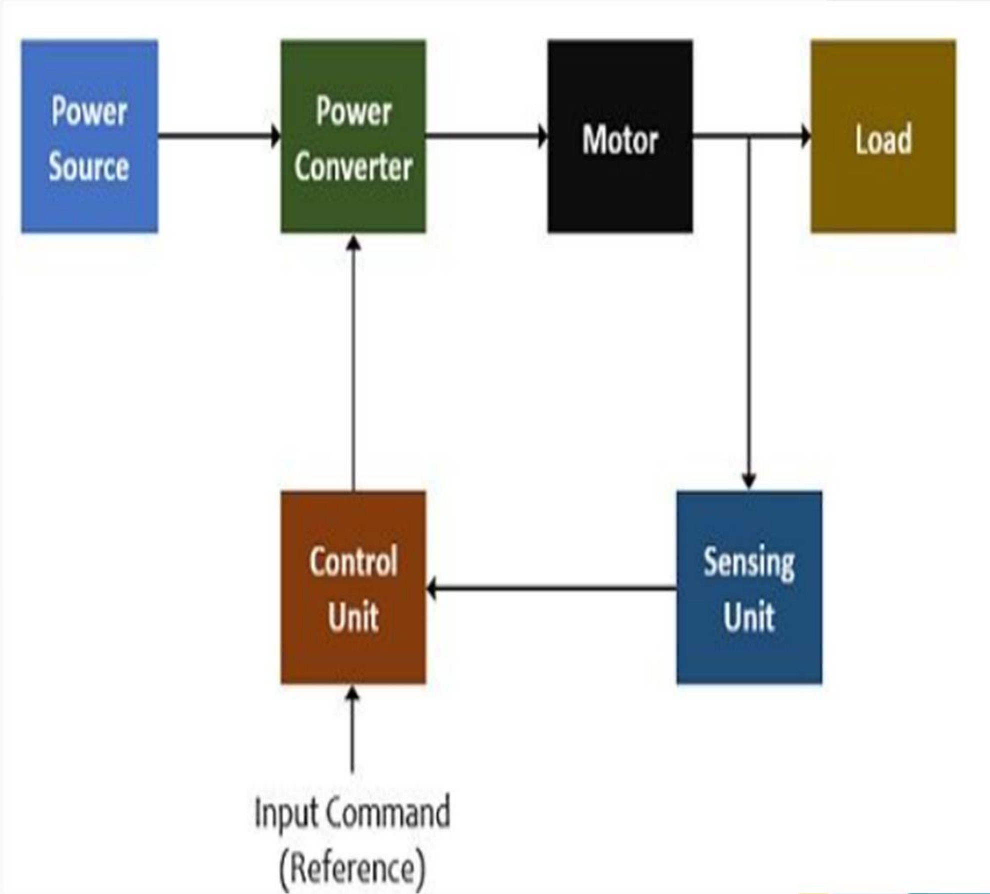
Q3_Dynamics and Control of AC/DC drives

Outline

- *Introduction*
- *Torque and speed control of structures of electrical drives*
- *Speed control methods of converter-fed DC motor drives*
- *Frequency-controlled induction motor drives*
- *Artificial intelligence methods in electrical drives*

Introduction

- Electric Drives are electromechanical systems designed to control the motion of electrical machines.
- It is very important component of different industrial processes equipment as it helps in easy optimization of motion controlling and
- It is regarded as a complicated control system that controls the rotation shaft of the motor.

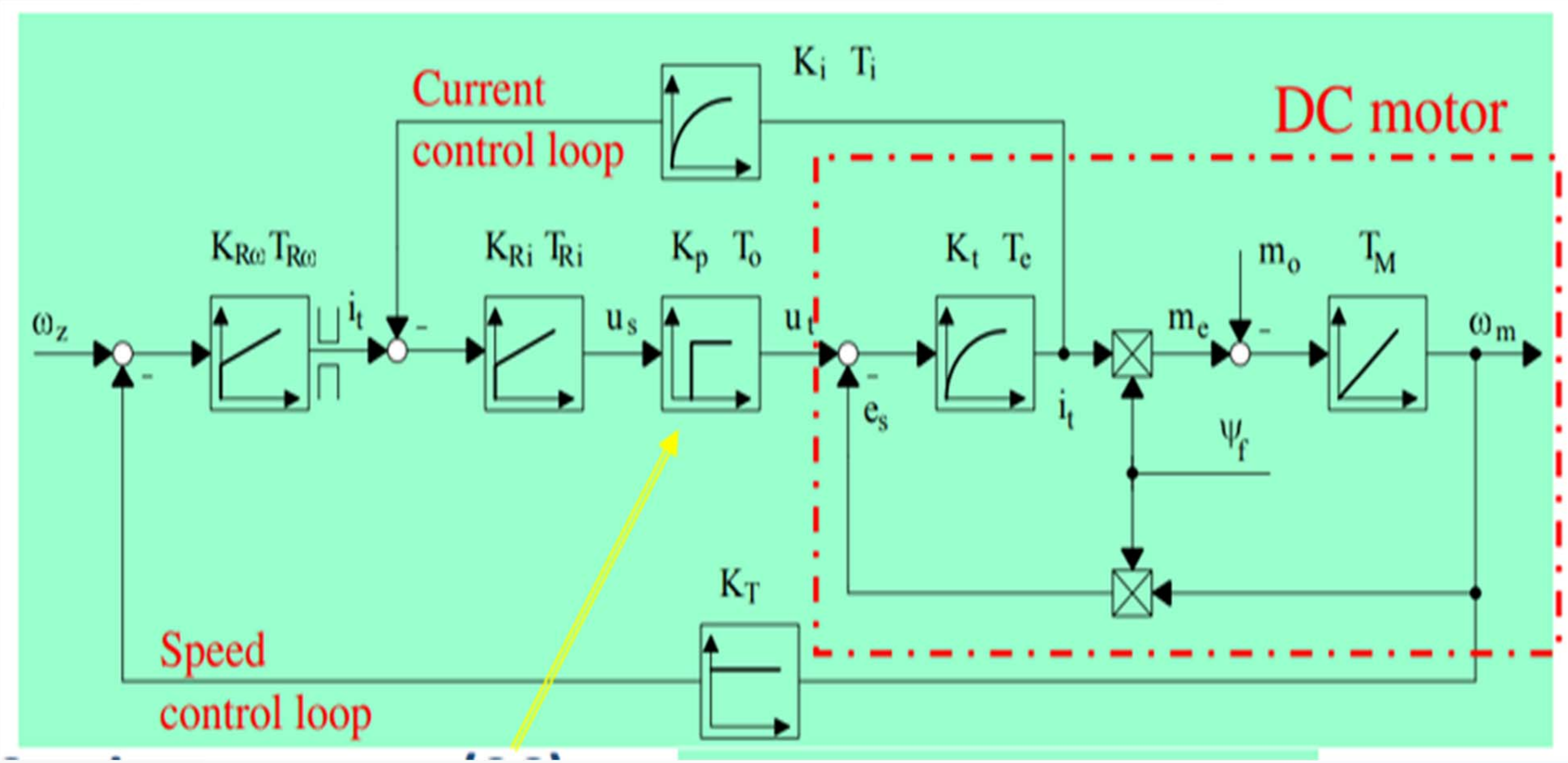


Torque and speed control of structures of electrical drives

Based on the general overview of torque and speed control structures for electrical drives, we have 3 basic control structures for DC drives:

1. series control structure (cascaded),
2. parallel control structure (it is the same as the direct voltage control structure),
3. structure with the supervised torque control loop (the special type of cascade control).

Cascaded control structure of DC drives

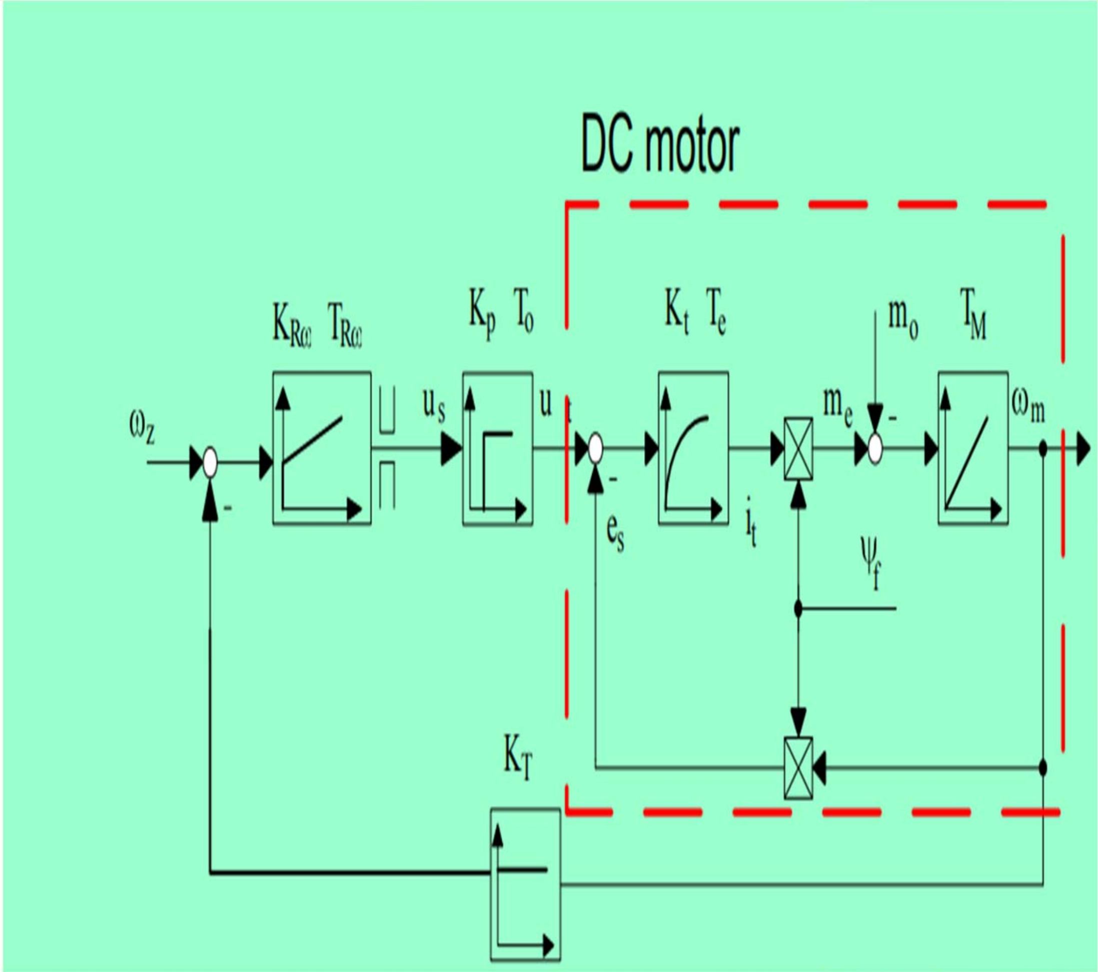


Con..

- **Electromagnetic time constant T_e of the motor (the biggest time constant in the optimized loop) was compensated by the optimized current controller *Ri,***
- **Optimized current control loop is approximately the first order inertial element with the substitute time constant T_{zi} (T_{zi} takes into account the summ of all small time constants of the current loop: delay of the static converter - T_o and delay of the current sensor - T_i),**
- **In the optimized current control loop only small time constants were not compensated!**

Parallel control structure

- Under normal operation – only the speed controller is active; the current controller „waits for the „overloading
- Due to the optimization of PI-type speed controller we obtain:
- The compensation of the biggest time constant of the DC drive – mechanical time constant TM (only !);
- Electromagnetic time constant Te is not compensated and determines the dynamical properties of the drive system in the normal operation conditions;
- The current controller works only during the overloading operation of the system – it should be adjusted acc. to the Modulus Criterion (as in the case of cascade control structure – internal current loop);

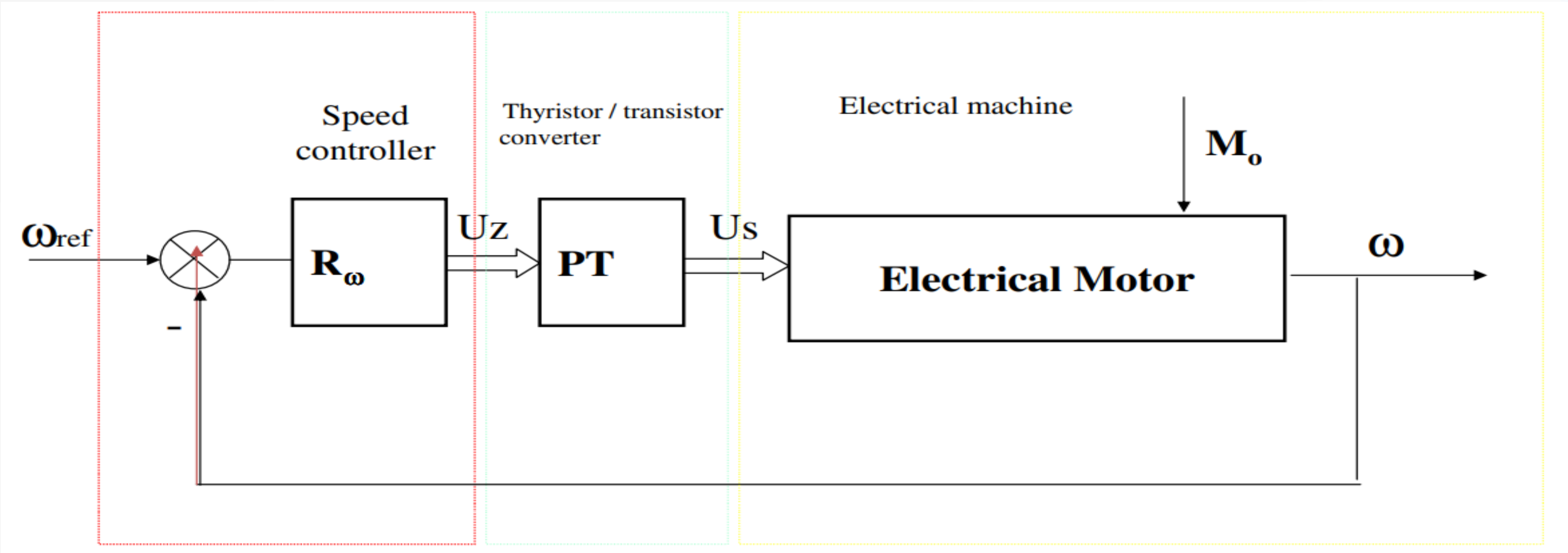


Speed control methods of converter-fed DC motor drives

- Structure with the direct voltage control (direct speed control structure)
- Parallel control structure
- Series control structure
- Structure with the supervised torque

Structure with the direct voltage control (direct speed control structure)

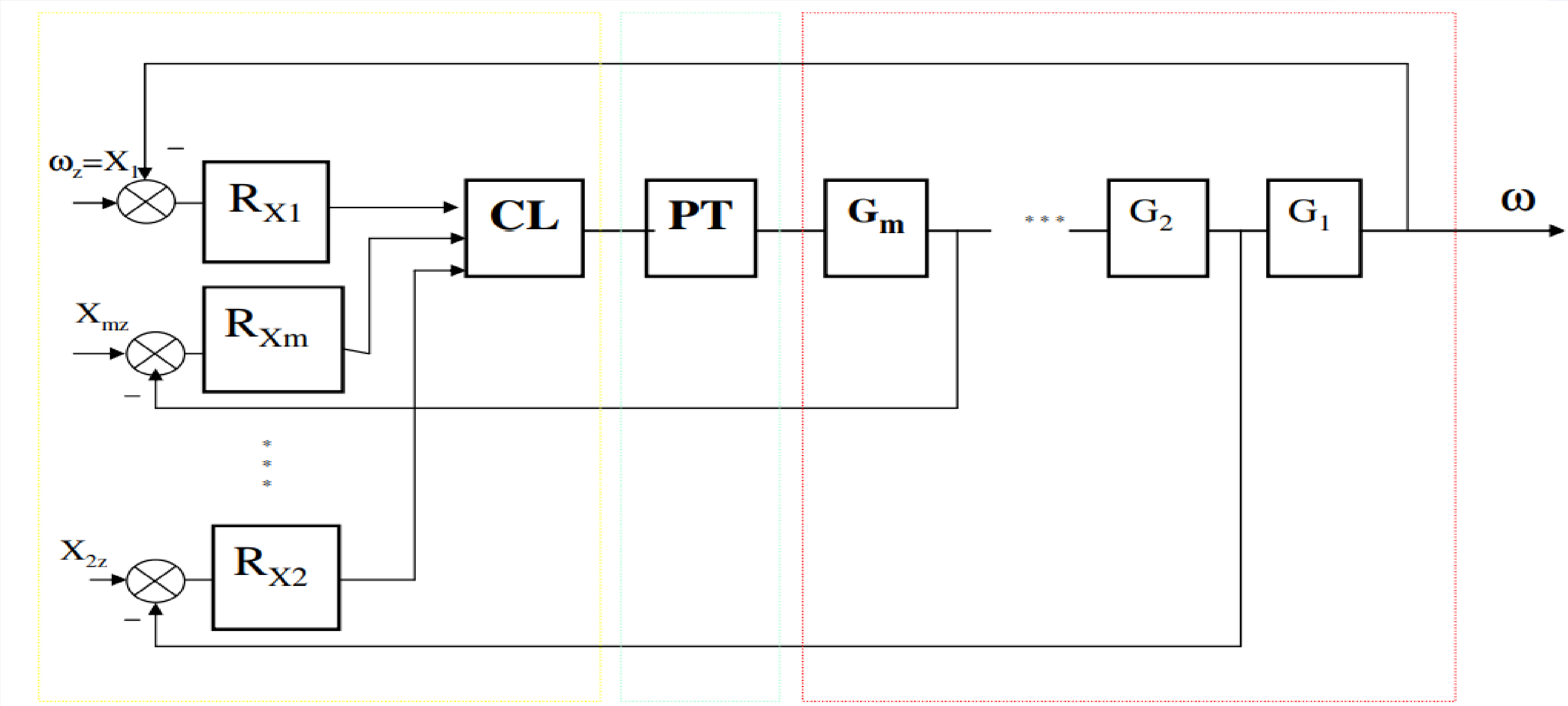
- Direct voltage control is a technique used in electric motor control to regulate the speed of the motor. The basic idea of direct voltage control is to vary the voltage applied to the motor to control its speed.
- A DC motor's speed is directly proportional to the input voltage.
- General scheme of the direct speed control structure in the converter-fed drive (with the direct voltage control)



- The direct speed control structure operates by measuring the actual speed of the motor using a speed-sensing device. The measured speed is then compared to the desired speed, which is set by the controller.

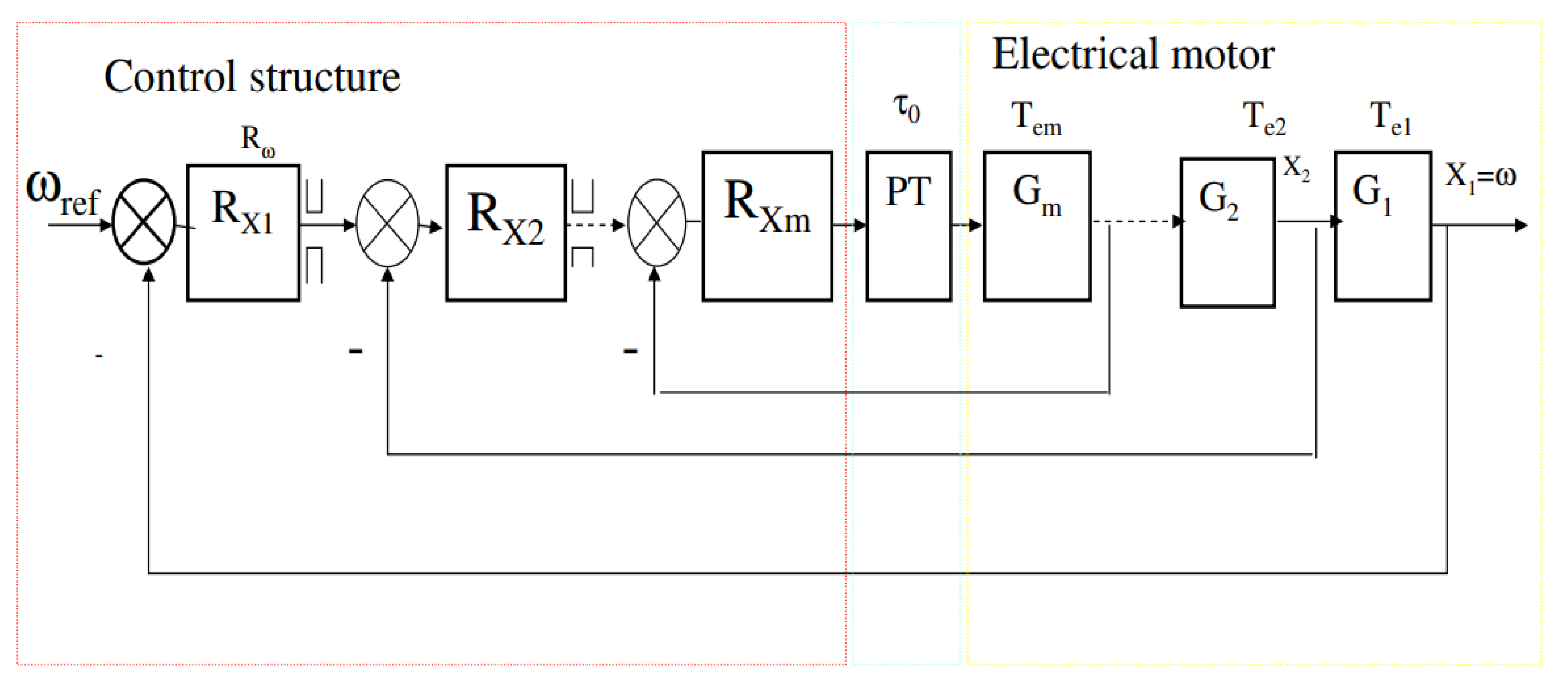
Parallel control structure

- In a parallel control structure, the speed and current loops operate independently, with the speed loop regulating the speed of the motor and the current loop regulating the current flowing through the motor.
- General scheme of the control structure with the parallel connection of state variable controllers.



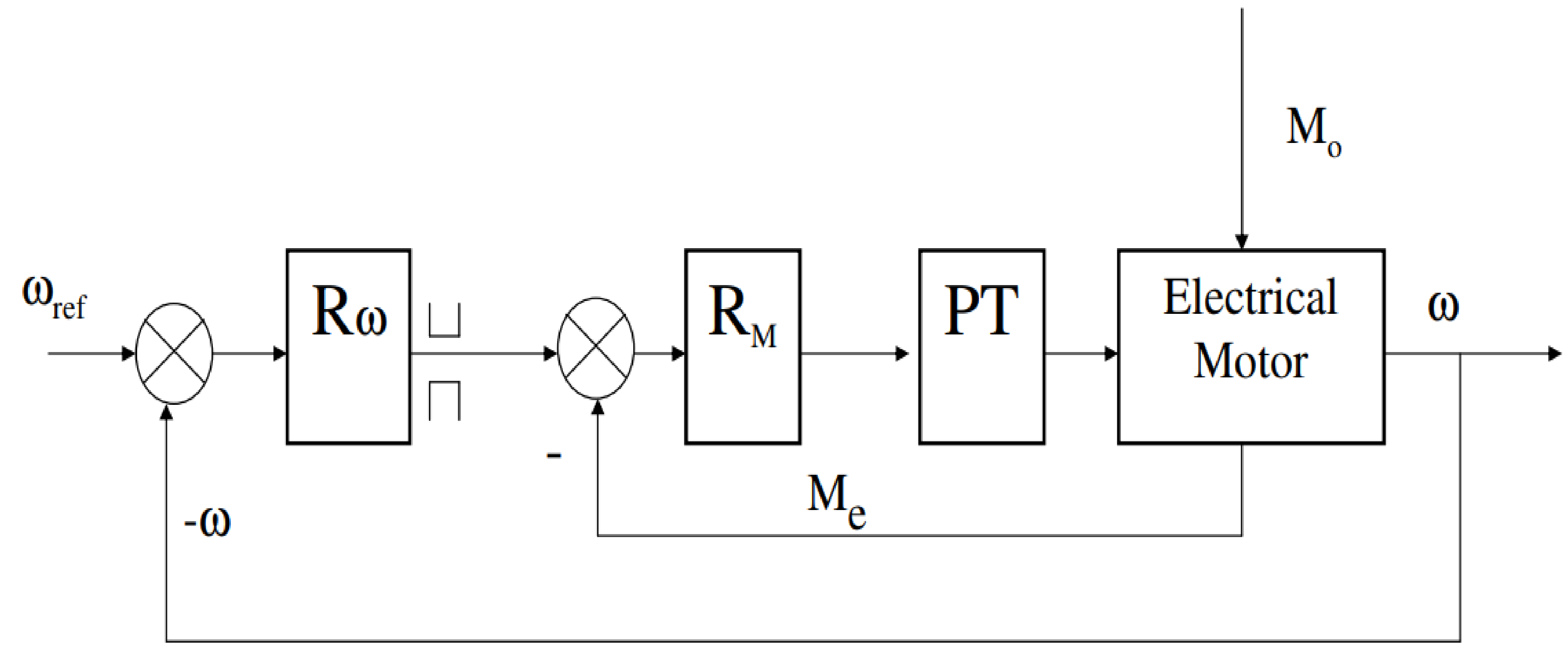
Series control structure

- In a series control structure, the control loops are arranged in series, meaning the output of one loop is the input of the next loop. For example, the outer loop(speed controller) waits its operation to the inner control loop(current controller).
- Therefore, a perfect operation of a series or cascaded control structure is possible only if the inner loop has a faster dynamic characteristic than the outer one.



Structure with the supervised torque

- A supervised torque controller is a type of controller used in motor control systems to regulate the torque output of the motor. The structure with the supervised torque controller includes a torque sensor, a speed sensor, and a controller that receives inputs from both sensors.
- Therefore, this structure needs electromagnetic torque measurement or torque estimation is required.
- It provides good control of the motor torque while maintaining a desired speed. However, this structure with the supervised torque controller may be more complex than other control structures, such as the series or parallel control structures, since it requires additional sensors or hardware elements.



Frequency-controlled induction motor drives

- The speed of an induction motor can be controlled by varying the frequency of the 3-phase supply; however, to maintain a constant (rated) flux density, the applied voltage must also be changed in the same proportion as the frequency.
- This speed control method is known as Volts per Hz.
- Above rated speed, the applied voltage is usually kept constant at the rated value.
- At low frequencies (i.e. speeds), the voltage must be boosted in order to compensate for the effects of the stator resistance.

Artificial intelligence methods in electrical drives

Industrial drive systems are characterized by different parameter and structural changes, like:-

- change of electromechanical time constant Tm (=f(J))
- change of dead time T_O (τ_O) of a static converter,
- change of the exciting flux value Ψf ,
- change of the electromagnetic time constant of the exciting winding Tf (due to magnetic characteristics).

These changes can cause the degradation of control performance, quality of technological process, even loss of stability of the drive systems.

- Hence, conventional methods of electric drives do not work that much efficient. Because of these reasons, artificial intelligent techniques are being applied to improve drive performances.
- Intelligence is a popular intellectual ability that involves capability to reason, plan, resolve complications, think abstractly, perceive ideas and learn. Generally, we can have:-

Artificial Neural Networks (ANN)

Fuzzy Logic (FL)

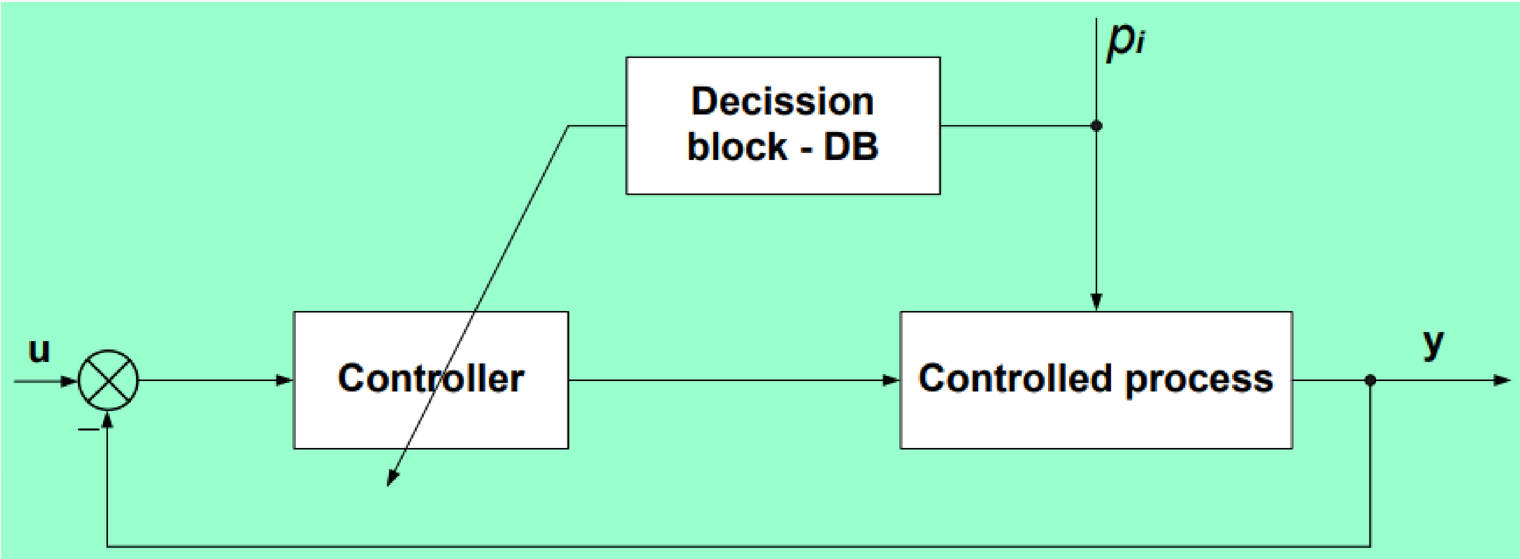
Genetic Algorithm (GA)

Adaptive control systems

Adaptive control systems are insensitive to parameter changes or noise disturbances and can be classified as: -switchable controllers and Model Reference Adaptive Systems (MRAS-direct, MFAS-indirect).

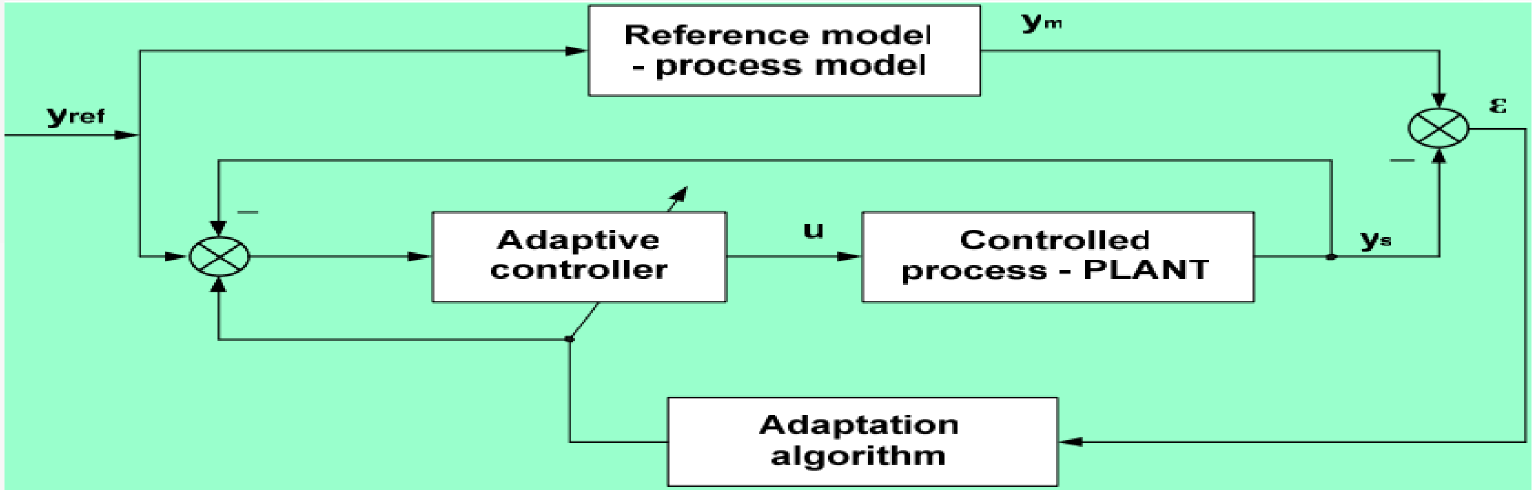
1. Switchable controller

- In such systems direct (by measurement) or indirect (by estimation) information on changeable parameters p_i of the controlled process is required.
- Based on this information, the decision block(DB) performs suitable changes in the structure and/or parameters of the adaptive controller.



Model Reference Adaptive System(MRAS)

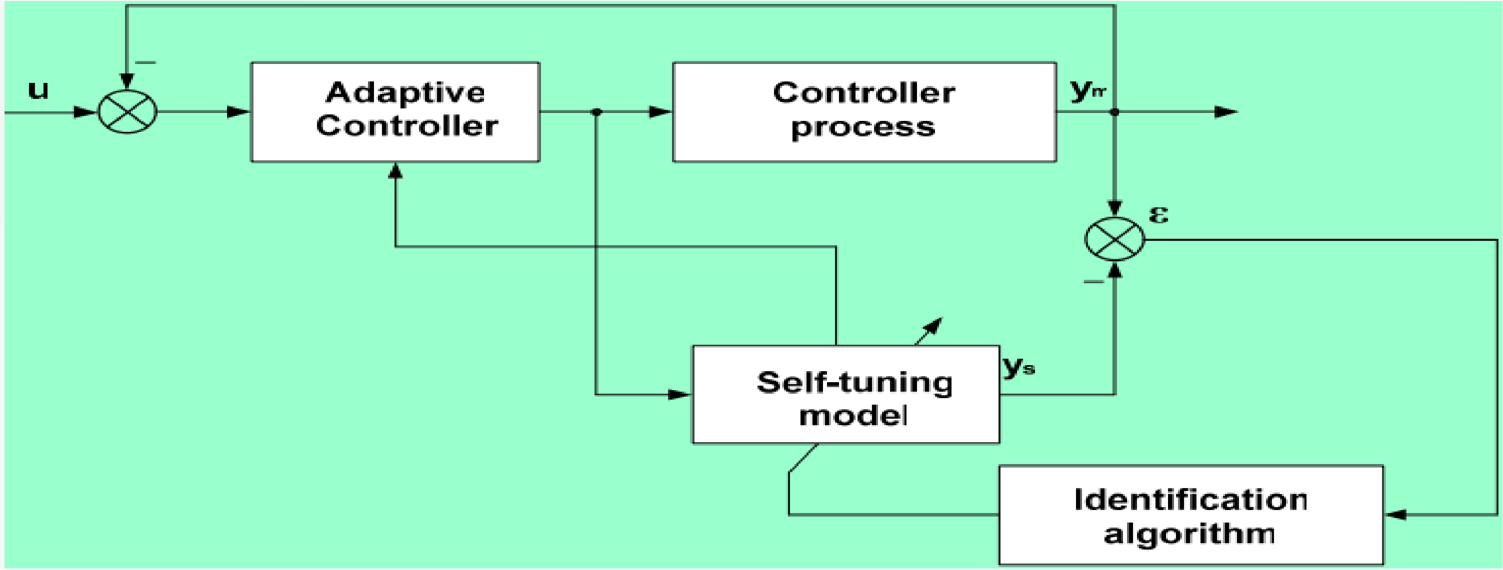
- Direct system(MRAS)-involves using a reference model to estimate the state variables of a drive system, such as rotor speed and torque, and comparing the estimated values to the actual measured values to generate an error signal.
- This error signal is then used to adaptively adjust the control parameters of the drive system in real time to improve its performance.



- Direct systems (MRAS) - simpler for practical realization - it doesn't require detailed knowledge of the system dynamics.
- The reference model forces the optimal system dynamics – optimal system response, regardless of the system parameter variations.
- However, its application is limited to the cases, when reference signal y_{ref} is variable – such a control concept can not be applied in a constant value reference systems.

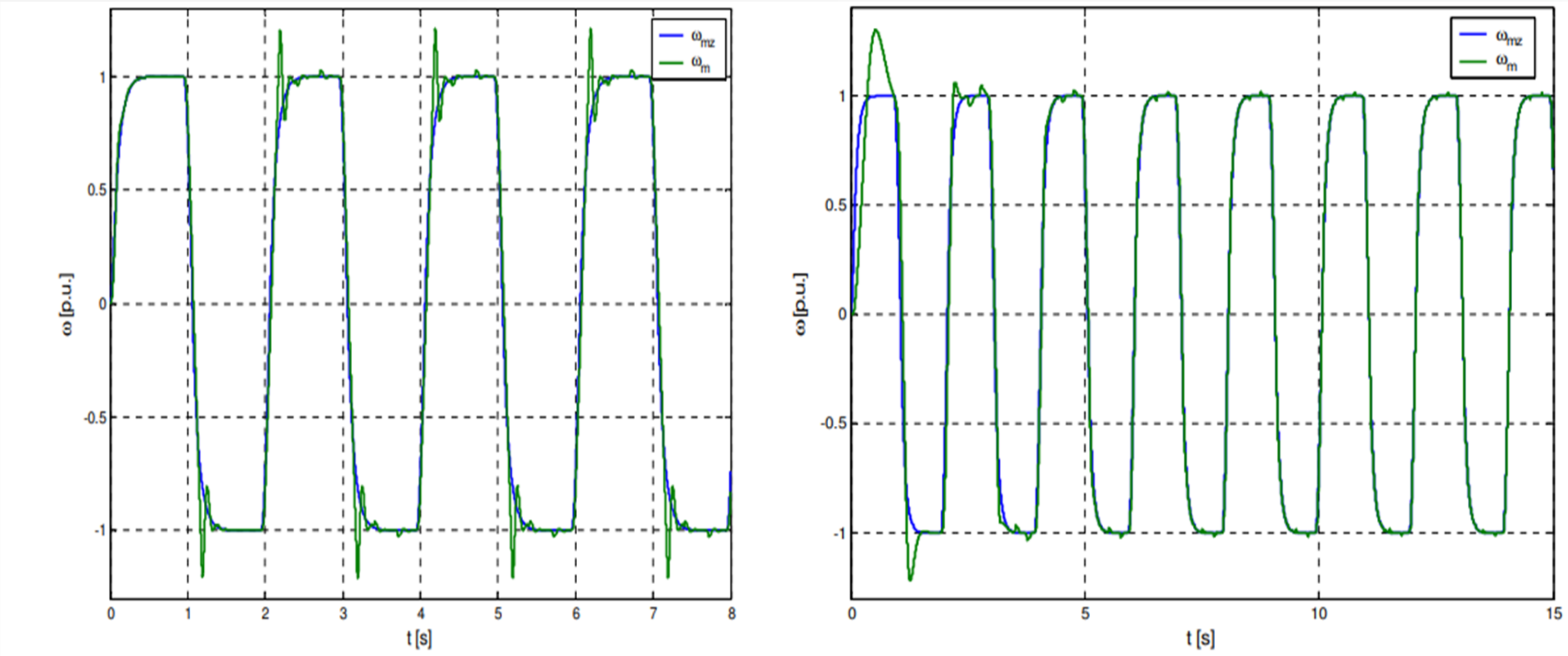
Model Following Adaptive System(MFAS)

- MFAS works by tracking(identifying) a reference model. The reference model is a mathematical model of the desired behavior of the drive system, and the MFAS uses this model to generate control signals that are used to adjust the drive system's behavior to match the reference model.



- Indirect system because it generates control signals to adjust the behaviour of the drive system to match a reference model, rather than directly estimating the state variables of the system.
- Bigger universality, due to the continuous identification of the plant, but it is more complicated in realization.
- It can be applied in the constant-reference systems which are not possible in the case of MRAS.

MRAS for DC motor drive



1 classical PI controller (cascade structure)
2. MRAS (cascade structure) (cascade structure with reference model

Thank you!