

ROBOT HAVING A CONTROLLER PROTECTED AGAINST A POWER NETWORK FAILURE

The invention relates to a robot having a controller which is protected against a power network failure (failure of the electrical energy required to operate the robot). For this purpose,
5 the robot has advantageously movable, actuator-driven elements.

Robots typically require electric power to operate. This power is supplied, particularly in the case of immobile robots, via an electric power supply unit of the robot, which is connected on the input side to an electric power source, typically to an electric power network. The electric power network or the electric power source may suffer failure for a number of reasons. When
10 such a failure occurs, for functional safety reasons it must be ensured that the robot, i.e. its movable elements in particular, will enter a safe state. Such a state is meant to ensure that the robot will not become damaged, will not cause any damage in the area surrounding it, and will be operable immediately once the electric power supply is restored, if at all possible without any problems and without requiring intervention.

15 The object of the invention is therefore to provide a robot that will enter a safe state, in particular with its moving elements, when a failure of the power supply occurs, and which will simply be ready to operate again once the network power supply is restored.

The invention will be clear from the features of the independent claims. Advantageous refinements and embodiments are the subject matter of the dependent claims. Other features,
20 applications and advantages of the invention will be apparent from the following description, and from the elucidation of exemplary embodiments of the invention, which are depicted in the figure.

The object is attained by a robot having actuator-driven elements, which requires a desired operating voltage U_B and/or a desired operating current I_B in order to operate. The robot comprises a voltage and current source (i.e. a power supply unit) having an input interface, to which a primary voltage U_P and a primary current I_P are applied, wherein during normal operation

5 the primary voltage U_P is equal (in terms of control and noise tolerances) to a desired primary voltage $U_{P,desired}$ and the primary current I_P is equal (in terms of control and noise tolerances) to a desired primary current $I_{P,desired}$, and also having an output interface, to which an actual voltage U_{actual} and an actual current I_{actual} are applied, wherein during normal operation (in terms of control and noise tolerances), $U_{actual} = U_B$ and $I_{actual} = I_B$, an energy store which is integrated into the

10 voltage and current source and which, following a failure or a drop in the primary voltage/primary current, maintains the operating voltage U_B and the operating current I_B for a predefined period of time Δt , a unit for monitoring the primary voltage U_P applied to the input interface, the unit being configured such that, as soon as the applied primary voltage U_P deviates from the desired primary voltage $U_{P,desired}$ by a predefined amount ΔU , a stop signal is generated, and a control

15 unit which is connected to said monitoring unit and which is designed for controlling the robot and the actuator-driven elements thereof, the control unit being configured to control the robot and the elements thereof into a predefined safe state upon receipt of the stop signal.

The term "actuator-driven elements" is interpreted broadly in the present case. It includes essentially all movable, actuator-driven elements of the robot, for example, members of a robot

20 manipulator, artificial limbs, drive wheels, etc.

The voltage and current source is preferably embodied as a power supply unit of the robot, with the robot being operated at a desired operating voltage U_B and/or a desired operating current

I_B , which is supplied to the output interface of the voltage and current source. The input interface of the voltage and current source is advantageously connected to an electric power network, typically a low voltage network (for example, a 230-240V power network or a 400-420V three-phase alternating current network). The voltage and current source advantageously converts the primary voltage U_P which is applied to the input side to the actual voltage U_{actual} which is supplied to the output interface. Typically, $U_{actual} < U_P$.

During normal robot operation, the actual voltage U_{actual} supplied to the output interface is equal to the desired operating voltage U_B ($U_{actual} = U_B$). In addition, during normal robot operation, the actual current I_{actual} supplied to the output interface is equal to the desired operating current I_B ($I_{actual} = I_B$).

According to the invention, the voltage and current source is further equipped with an energy store, which is integrated into the voltage and current source and which is designed and configured such that, following a failure or a drop in the primary voltage U_P or the primary current I_P at the input interface, the operating voltage U_B and the operating current I_B at the output interface are maintained for a predefined period of time Δt . The energy store is preferably equipped with one or more capacitors and/or one or more inductors and/or one or more accumulators for energy storage. The term "inductors" in the present case includes, for example, inductors, coils, transformers, etc. The dimensions of the energy store are advantageously dependent upon the amount of energy required by the robot to bring the robot from any dynamic state (any possible dynamic state of the operator) into a safe state.

The term "safe state" is interpreted broadly in the present case. It includes essentially any state of the robot that can be detected by means of sensors. In particular, the term includes a

predefined state of the movable elements of the robot, in particular a deceleration of all the movable elements of the robot into a predefined pose or a deceleration of all the movable elements of the robot into said state without a predefined pose. The "safe state" may further include, for example, electrical states and data-related states of the robot. For instance, the safe state may include a data backup, etc.

Advantageously, once the stop signal has been received, the control unit quasi instantaneously initiates the establishment of the safe state, in particular initiating a deceleration process of the actuator-driven movable elements of the robot into a mechanical safe state. The safe state is advantageously predefined appropriately depending upon the task set for the robot, and advantageously meets the condition that, during the establishment of the safe state, in particular by decelerating the movable elements of the robot into the safe mechanical state, the robot does not present a threat to its environment or to itself.

The dimensions of the energy store are advantageously selected such that in the event of a total failure of the primary voltage U_P /primary current I_P applied to the input interface it is ensured that the operating voltage U_B and the operating current I_B at the output interface are maintained for the predefined period of time Δt . The period of time Δt is advantageously a required period of time during which the robot can be brought from any state into a safe state.

Appropriate dimensions of the energy store thus ensure that, even with a total failure of the voltage or current supply to the input side of the voltage and current source, it is always ensured that the robot can be transferred from any state into a safe state. The state referred to as "any" state is any element of the set of all the states that the robot is able to occupy.

One advantageous refinement of the proposed robot is characterized in that actuators of the driven elements are designed for the recuperation of electric power and can be connected to the integrated energy store. Thus, it is advantageously possible to convert kinetic energy of the movable elements of the robot during the deceleration process into electrical energy and to use
5 this energy to increase the energy stored in the energy store.

One advantageous refinement of the proposed robot is characterized in that the unit is designed such that the controlling of the robot into the predefined safe state comprises a triggering of the mechanical deceleration of the driven elements. Advantageously, the mechanical brake(s) is/are triggered only when the robot has been decelerated by actuators into a dynamic state which
10 is preferably characterized by the sum of the kinetic energy of some or all of the movable elements of the robot, which is less than one predefined boundary kinetic energy. It can thereby be ensured that an abrupt intervention by mechanical brakes takes place only when no mechanical or other damage to the robot will be caused by engagement of the mechanical brakes. Prior to this point, the robot, i.e. its actuator-driven movable elements, is preferably decelerated by
15 actuators. This refinement increases the availability of the robot system, since a firm response by mechanical brakes with the associated risk of mechanical damage is generally avoided.

According to one advantageous refinement of the proposed robot, the stop signal is transmitted as an encrypted data signal via the symmetrically configured data link from the unit to the control unit. Further advantageously, the stop signal is an optical signal and the data link is
20 configured for transmitting optical signals.

In principle, any wired or fiber optic transmission method is suitable for this transmission: analog voltage, digital signal (direct or modulated), communication protocol. The latter two

groups are optically transmittable; this is advantageous because isolation is simultaneously achieved as a result (i.e., detection at the input interface with high voltage, processing at the output interface typically with lower voltage).

The stop signal is advantageously a high priority signal to the control unit of the robot
5 indicating that a power failure at the output interface is imminent.

Advantageously, when a drop in voltage occurs at the output interface, mechanical brakes are engaged immediately so that the movable elements of the robot are decelerated almost instantaneously. Thus, a safe initiation of a deceleration process is always ensured. In this case, a reliable implementation of the energy storage function is not necessary, because the mechanical
10 deceleration process is initiated independently of the energy that is available in the energy store.

Further advantages, features and details will be apparent from the following description, in which at least one exemplary embodiment is described in detail, with reference to the drawings where appropriate. The same, similar and/or functionally equivalent parts are provided with the same reference signs.

15 In the drawings:

Fig. 1 shows a schematic diagram of one embodiment of the proposed robot.

Fig. 1 shows a schematic diagram of one embodiment of the proposed robot having actuator-driven elements 105, which requires a desired operating voltage U_B and/or a desired operating current I_B for operation. The robot comprises a voltage and current source 101 having
20 an input interface 107 to which a primary voltage U_P and a primary current I_P are applied, wherein

during normal operation, the primary voltage U_P is equal to a desired primary voltage $U_{P,desired}$ and the primary current I_P is equal to a desired primary current $I_{P,desired}$, and also having an output interface 108 to which an actual voltage U_{actual} and an actual current I_{actual} are applied, wherein during normal operation: $U_{actual} = U_B$ and $I_{actual} = I_B$.

5 Voltage and current source 101 comprises an energy store 102 integrated therein, in the present case comprising a plurality of capacitors which, following a failure or a drop in the primary voltage/primary current, maintain the operating voltage U_B and the operating current I_B at the output interface 108 for a predefined period of time Δt .

10 Voltage and current source 101 further comprises a transformer 106, which transforms the primary voltage U_P supplied to the input interface 107 into a low-voltage range and supplies it to output interface 108 as the actual voltage U_{actual} .

15 The robot further comprises a unit 103 for monitoring the primary voltage U_P applied to input interface 107, with the unit 103 being designed in such a way that as soon as the applied primary voltage U_P deviates from the desired primary voltage $U_{P,desired}$ by a predetermined amount ΔU , a stop signal is generated.

 Finally, the robot comprises a control unit 104, which is connected to unit 103 and is designed for controlling the robot and its actuator-driven elements 105, with the control unit 104 being configured to control the robot with its elements 105 into a predefined safe state upon receipt of the stop signal.

20 In Fig. 1, the load current paths are indicated by bold arrows. The thinner arrows proceeding from unit 103 to control unit 104 and from there to the actuator-driven elements of

the robot are data lines. Advantageously, the stop signal is an optical signal and the data lines are configured as optical fibers.

Although the invention has been further illustrated and described in detail by way of preferred exemplary embodiments, the invention is not restricted by the disclosed examples, and
5 other variations may be derived from said examples by those skilled in the art, without departing from the scope of the invention. It is therefore clear that a multitude of possible variations exists. It is also clear that cited, exemplified embodiments are actually merely examples, and are not to be construed in any way as limiting the scope, applicability, or configuration of the invention. Rather, the foregoing description and the description of the figures enable a person skilled in the
10 art to implement the exemplary embodiments, and those skilled in the art with knowledge of the disclosed inventive concept may make various modifications, for example as to the function or the arrangement of individual elements cited in an exemplary embodiment, without departing from the scope as defined by the claims and their legal equivalents, such as the detailed explanations in the description.

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List of Reference Signs

	101	voltage and current source/power supply unit
	102	energy store integrated into the voltage and current source
	103	unit
5	104	control unit
	105	actuator-driven elements of the robot
	106	transformer
	107	input interface
	108	output interface

CLAIMS

1. A robot having actuator-driven elements (105), which requires a desired operating voltage U_B and/or a desired operating current I_B in order to operate, comprising:

- 5 - a voltage and current source (101) having an input interface (107), to which a primary voltage U_P and a primary current I_P are applied, wherein, during normal operation, the primary voltage U_P is equal to a desired primary voltage $U_{P,desired}$ and the primary current I_P is equal to a desired primary current $I_{P,desired}$, and also having an output interface (108), to which an actual voltage U_{actual} and an actual current I_{actual} are supplied, wherein during normal operation: $U_{actual} = U_B$ and $I_{actual} = I_B$,
- 10 - an energy store (102), which is integrated into the voltage and current source (101) and which maintains the operating voltage U_B and the operating current I_B for a predefined period of time Δt following a failure or a drop in the primary voltage/primary current,
- 15 - a unit (103) for monitoring the primary voltage U_P applied to the input interface (107), wherein the unit (103) is configured such that as soon as the applied primary voltage U_P deviates by a predefined amount ΔU from the desired primary voltage $U_{P,desired}$, a stop signal is generated, and
- 20 - a control unit (104), which is connected to the unit (103) and is designed for controlling the robot and its actuator-driven elements (105), wherein the control unit (104) is configured to control the robot (105) with its elements (105) into a predefined safe state upon receipt of the stop signal.

2. The robot according to Claim 1,

in which actuators of the actuator-driven elements (105) can be connected to the integrated energy store (102) for the recuperation of electrical energy.

3. The robot according to Claim 1 or 2,

5 in which the unit (103) is embodied and configured in such a way that controlling the robot into the predefined safe state comprises a triggering of mechanical brakes of the driven elements.

4. The robot according to any one of Claims 1 to 3,

in which the energy store (102) comprises one or more capacitors and/or one or more inductors and/or one or more accumulators.

10 5. The robot according to any one of Claims 1 to 4,

in which the stop signal is transmitted in the form of a symmetrical and encrypted data signal from the unit (103) to the control unit (104) via the data link.

6. The robot according to any one of Claims 1 to 5,

15 in which the stop signal is an optical signal and the data link is configured for the transmission of optical signals.