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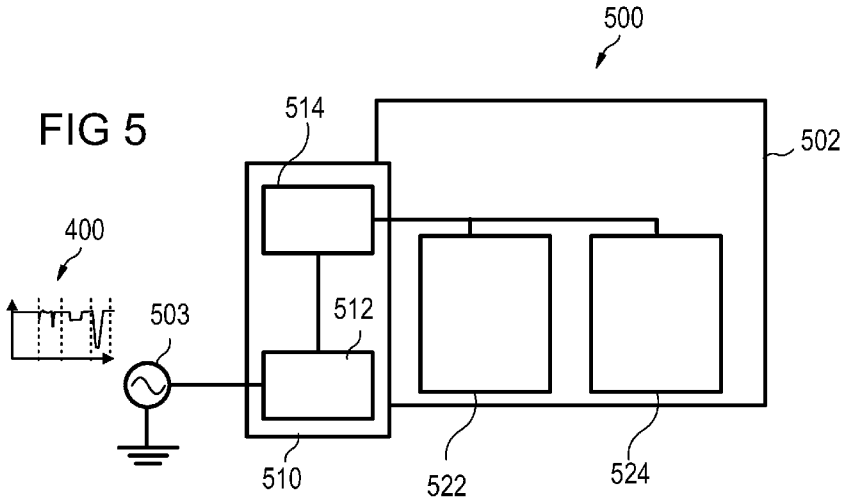
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(54) Title: WIRE SAW DEVICE, METHOD OF OPERATING THEREOF

FIG 5



(57) Abstract: A method of operating a wire saw device is described. The method includes operating the wire saw device at a first set of predetermined parameters, the parameters including a first wire speed of a sawing wire, measuring values of one or more physical quantities being a physical quantity of the power supply grid providing power to the wire saw device or a DC converted voltage of the power supply grid, determining one or more deviations of respective values of the one or more physical quantities from desired values of the physical quantities, and operating the wire saw device at a second wire speed smaller than the first wire speed depending on the determined one or more deviations

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WIRE SAW DEVICE, METHOD OF OPERATING THEREOF

FIELD OF THE INVENTION

[0001] Embodiments of the present invention relate wire saw devices and methods of operating wire saw devices. More particularly, they relate to the operation of wire saw devices in a safe mode, wire saw devices with controllers for operation thereof, and computer program products for wire saw devices.

BACKGROUND OF THE INVENTION

[0002] Wire saw devices exist for cutting blocks or bricks, thin slices, e.g. semiconductor wafers, from a piece of hard material such as silicon. In such devices a stretched wire is fed from a spool and is both guided and tensioned by pulleys for guiding the wire in the cutting area. The wire that is used for sawing is generally provided with an abrasive material. As one option, the abrasive material can be provided as a slurry. This may be done shortly before the wire touches the material to be cut. Thereby, the abrasive is carried to the cutting position by the wire for cutting the material. As another option, the abrasive can be provided on the wire with a coating. For example, diamond particles can be provided on a metal wire, e.g. with a coating, wherein the diamond particles are imbedded in the coating of the wire. Thereby, the abrasive is firmly connected with the wire.

[0003] Generally, there is a tendency to use thinner wires in order to reduce the thickness of the cut and, thereby, to decrease the material wasted. There is also a desire to use diamond wires. Further, there is a desire to increase the cutting speed for improving the throughput of wire saw devices. The maximum speed for moving the piece through the web, and also the maximum effective cutting area within a given amount of time, is limited by several factors including wire speed, hardness of the material to be sawed, disturbing influences, desired precision, and the like. When the speed is increased and/or diamond wires are used, the probability of wire breakage during certain operational conditions is increased. However, wire breakage results in down-time of the device, which significantly reduces throughput. The above-mentioned problems of avoiding damage or breakage of the wire are even more

critical at higher sawing speeds and with thinner wires. Accordingly, there is a desire for improved control of wire saws and improved operation methods in order to avoid breakage of the wire.

SUMMARY

[0004] In view of the above, a method of operating a wire saw device according to independent claim 1, a computer program product having a program code according to claim 11, and a wire saw apparatus or device according to claim 12 are provided. Further advantages, features, aspects and details are apparent from the dependent claims, the description and drawings.

[0005] According to one embodiment, a method of operating a wire saw device is provided. The method includes operating the wire saw device at a first set of predetermined parameters, the parameters including a first wire speed of a sawing wire, measuring values of one or more physical quantities being a physical quantity of the power supply grid providing power to the wire saw device or a DC converted voltage of the power supply grid, determining one or more deviations of respective values of the one or more physical quantities from desired values of the physical quantities, and operating the wire saw device at a second wire speed smaller than the first wire speed depending on the determined one or more deviations.

[0006] According to a further embodiment, a computer program product having a program code, which is provided on a machine readable device or in a memory of a controller of a wire saw device, is provided. The product conducts a method when operated on a computer or the controller of the wire saw device. The method includes operating the wire saw device at a first set of predetermined parameters, the parameters including a first wire speed of a sawing wire, measuring values of one or more physical quantities being a physical quantity of the power supply grid providing power to the wire saw device or a DC converted voltage of the power supply grid, determining one or more deviations of respective values of the one or more physical quantities from desired values of the physical quantities, and operating the wire saw device at a second wire speed smaller than the first wire speed depending on the determined one or more deviations.

[0007] According to a yet further embodiment, a wire saw apparatus having a wire for forming a wire web is provided. The wire saw device includes an electrical connector

adapted to connect the wire saw device to a power supply grid, a measuring unit adapted to measure values of one or more physical quantities being a physical quantity of the power supply grid or a DC converted voltage of the power supply grid providing power to the wire saw device, and a control unit being operatively connected to the measuring unit and adapted for measuring one or more deviations of respective values of the one or more physical quantities from desired values of the physical quantities of the power supply grid, wherein the control unit is adapted to operate the wire saw device in a safe operation mode.

[0008] Embodiments are also directed at parts used for carrying out the disclosed operation method. Furthermore, embodiments according to the invention are also directed at methods by which the described wire saw device operates.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the invention and are described in the following:

FIG. 1 shows a schematic view of a wire saw apparatus according to embodiments described herein;

FIG. 2 shows a schematic view of a portion of a yet further wire saw device according to embodiments described herein;

FIG. 3 shows a perspective view of a wire management unit;

FIG. 4 shows a schematic view of a graph illustrating the voltage provided from a grid to a wire saw device;

FIG. 5 shows a schematic view of a yet further wire saw device adapted for improved control of operational conditions;

FIG. 6 shows a flow chart illustrating methods of operating a wire saw device according to embodiments described herein;

FIG. 7 shows a flow chart illustrating yet further methods of operating a wire saw apparatus according to embodiments described herein; and

FIG. 8 shows a schematic view of a yet further embodiment of a wire saw device adapted for improved control of operational conditions.

DETAILED DESCRIPTION OF THE INVENTION

[0010] Reference will now be made in detail to the various embodiments of the invention, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. Generally, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the invention and is not meant as a limitation of the invention. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

[0011] Furthermore, in the following description a wire management unit will be understood as a device handling the supply of wire to a cutting area or working area of a wire saw apparatus or device, such as a cropper, i.e. a cropping wire saw device, a squarer, i.e., a squaring wire saw device, or a wafer cutting wire saw. Typically, the wire saw includes a wire guide for transporting and guiding the wire in a wire moving direction while the wire management unit provides control of the wire tension. Thereby, a wire tensioning arm can be provided to control the tension during spool up or spool down the wire from and to a spool. Furthermore, the wire provided by the wire management unit forms a wire web in the cutting area. Often, a wire web will be considered as the web formed by a single wire management unit. It should be understood that a wire web may contain more than one working area which is defined as an area in which a sawing process is performed. Thus, according to some embodiments described herein, a wire web can have multiple areas that are formed by a wire from different wire management units.

[0012] For modern wire saw devices like croppers, i.e. a cropping wire saw devices, squarers, i.e., a squaring wire saw device, or wire saws, i.e. wafering wire saw devices, there is the desire to cut the hard material such as semiconductor material, for example silicon, quartz, or the like at high speeds. The wire speed, that is, the speed of the wire moving through the wire

saw device, the wire management unit and the material to be sawed, respectively, can be, for example, 10 m/s or higher. Typically, the wire speed can be in a range of 8 to 30 m/s. However, higher wire speeds of 25 m/s or 30 m/s can also be desirable and could be realized under certain conditions.

[0013] For unwinding the wire at the desired wire speed, the spool rotates with a rotation speed of up to several thousands rotations per minute. For example, 1000 to 2000 rpm can be provided for unwinding the wire.

[0014] FIG. 1 shows a wire saw device or apparatus 100. As can be seen from the pattern of the wire 10 forming the wire web in the wire web compartment 110, the example shown in FIG. 1 illustrates a wire saw for cutting wafers. The housing of the wire saw device is separated into different areas as indicated by the dotted line. The wire web is formed in the wire web compartment 110. Further, a housing portion 111, which houses further components and equipment of the wire saw device 100 is provided. As can be seen from the wire web formed by the wire 10 in the wire web compartment 110, the system shown in FIG. 1 can be used to slice wafers, i.e. the system is a wire saw. According to the embodiments illustrated with respect to FIG. 1, two wire handling compartments 112a and 112b are provided. The embodiments described herein, can be used for cropping wire saw devices, for squaring wire saw devices and for wafering wire saw devices. However, particularly for wafering wire saw devices, for which the cutting length of the wire is longer than for one of the other applications, a wire breakage might be more likely and might also be more deteriorating for throughput and waste of, e.g., silicon material. Thus, the invention might particularly be used for a wafering wire saw device.

[0015] According to some embodiments, which can be combined with other embodiments described herein, a first tank can be used for unused cooling fluid or fresh coolant, e.g. in the case where the wire saw device is operated with diamond wire, or can be used e.g. for unused (fresh) slurry, in the case where the wire saw device 100 is operated with a wire requiring additional abrasive. A pump pumps the cooling fluid (or slurry, respectively) towards the desired position in the cutting area. The used cooling fluid (or slurry) may flow back through a conduit and is pumped by a further pump into a second tank. In those cases where cooling fluid or slurry is used, a portion of or all of the used consumable fluid can be re-used if it is reinserted into the first tank. Thus, according to different embodiments only a portion of the consumable fluid, all of the consumable fluid or none of the consumable fluid may be reused and, thus, be reinserted in tank.

[0016] In the wire handling compartments 112a and 112b two handling sections for delivering the wire 10 to the cutting area and receiving the wire from the cutting area, respectively, are provided. According to some embodiments, which can be combined with other embodiments described herein, the wire is provided on a spool 132/132b rotating around the spool axes. The wire is guided over a plurality of rollers 134 into the wire web compartment 110. Further pulleys 134 guide the wire 10 into the cutting area to form the wire web. After cutting, the wire is guided by a further pulley 134 towards the wire handling compartments 212a and 212b and is therein provided over pulleys 134 onto the spool 130/130b rotating around the spool axes.

[0017] According to yet further embodiments, which can be combined with other embodiments described herein, the wire handling system can be adapted for bi-directional use, such that in one direction the wire is fed from spool 132 to spool 130 and in a further direction, the wire is fed from spool 130 to spool 132. Thereby, according to typical implementations the two units corresponding to spools 130 and 132 include similar components such as pulleys or the like, to have a corresponding wire handling in both sawing directions. The bi-directional use of the wire saw device, i.e. sawing directions back and forth of the wire saw device, may be of particular interest if diamond wire is used.

[0018] Typically, the wire is guided from the wire handling compartment to the wire cutting area and back with a wire speed of 10 m/s or higher, typically in a range of 15 to 20 m/s or even up to 25 m/s or 30 m/s. The material to be cut is positioned on the support. A support for the material to be sawed and the wire web can be moved relative to each other such that the cutting of the material can be conducted. According to one embodiment, the web can remain in a fixed position and the support moves the material to be cut through the wire web while the wire is at a speed of about 10 m/s or higher. For easier understanding, this movement of the support would in FIG. 1 be perpendicular to the plane of the drawing. According to another embodiment, the web generated by wire 10 is moved relative to the support to cut the wire through the material. According to a yet further embodiment, both the support and the wire web can be both moved with respect to each other.

[0019] According to yet further alternative or optional modifications, the wire web is formed by two adjacent areas wherein wire from each of the wire handling units is used to form one area of the wire web. According to different embodiments, a wire saw device can be a cropper, a squarer, a wire saw or a multiple wire saw. Thereby, a cropper is to be understood as a device, which can be used to saw end-pieces or middle-pieces from bricks or blocks,

which have been separated into bricks in a squarer. A squarer is a wire saw that generally saws the silicon ingot into squares of the desired size such that a wire saw or a multiple wire saw can saw wafers from the bricks in a wafering process.

[0020] The above-described systems are particularly useful if thin wires or wires with a coating, e.g. a diamond coating, are used. Accordingly, in embodiments which can be combined with other embodiments described herein, the wire handling sections and wire saw devices described herein are adapted for thin wires having a diameter below about 400 μm, such as diameters between about 80 μm and about 500 μm, more particularly between about 200 μm and about 300 μm. However, in other cases embodiments may also have a wire diameter as low as, for example, 100 μm or even 80 μm. Further, the wire saw operation processes and wire saw devices described herein are adapted for coated wires, for example a wire having a nickel coating with diamond particles embedded therein. Such wires may typically have a diameter of about 300 μm to about 400 μm, e.g. 310 μm to 340 μm. For those wires a twisting of the wire might increase the risk of breaking of the wire or of damaging the coating, so that a twist-free operation and an operation without or with reduced vibration is advantageous. By using diamond wire, the throughput may be increased by a factor of 2 or even more. When a diamond wire is used, further parts of the wire saw may be adapted to the diamond wire. For example, mechanical parts, electrical parts and/or software may be adapted to the use of diamond wire.

[0021] Fig. 2 shows a schematic front view of a wire saw device 102 illustrating further embodiments. The wire saw device 102 has a wire guide device including four wire guide cylinders 212, 214, 216, 218. A wire management unit 230 provides a wire to the wire guide cylinders 212, 214, 216, 218. The wire management unit 230 includes a supply spool 234 on which a wire reservoir, typically holding several hundred kilometers of wire, is provided. Fresh wire 235 is fed to the wire guide device from supply coil 234. Furthermore, the wire management unit 230 includes a take-up spool 238 on which the used wire 245 is recoiled.

[0022] The wire is spirally wound about the wire guide cylinders and forms between two wire guide cylinders layers 200 with working areas 210 and 220 of parallel wires. This layer is typically referred to as a wire web 200. Typically, wire guide cylinders 212, 214, 216, 218 are covered with a layer of synthetic resin and are scored with grooves having very precise geometry and size. The distance between the grooves determines the distance D1 between two adjacent strings or lines of wire. Furthermore, each wire guide cylinder 212, 214, 216, 218 is connected to a motor 222, 224, 226, 228 (shown in broken lines in Fig. 2). In the

embodiment shown in Fig. 2, wire guide cylinders 212, 214, 216, 218 are directly driven by motors 222, 224, 226, 228. As shown in Fig. 2, each wire guide cylinder may be directly mounted to the motor shaft of the corresponding motor. In some embodiments one or more of the motors are water-cooled. During operation, e.g. during the sawing process, the motors 222, 224, 226, 228 drive the wire guide cylinders 212, 214, 216, 218 so that the wire guide cylinders rotate about their longitudinal axis. Thus, the wire in wire web 200 is transported into a wire transport direction 215, 225. In one embodiment, one of the motors, e.g. motor 222, serves as a master motor whereas the remaining motors 224, 226, 228 serve as slave motors. In other words, master motor 222 controls the operation of slave motors 224, 226, 228 so that slave motors 224, 226, 228 follow master motor 222. Thus, synchronicity of operation of motors 222, 224, 226, 228 is improved and can be maintained during the sawing process.

[0023] The material to be sawed, e.g. blocks 202, 204, 206, 208 of semiconductor material, is attached to a holder. For example, silicon ingots 202, 204, 206, 208 may be mounted to a support mechanism which is not shown in Fig. 2. In order to saw blocks 202, 204, 206, 208, the blocks 202, 204, 206, 208 are lowered toward web 200. The wire is transported in wire moving direction 215, 225 at a considerable speed, e.g. between 15 m/s and 20 m/s. When blocks 202, 204, 206, 208 are pressed against the wire web 200 in a working area 210, 220 of web 200, the moving wire abrades the semiconductor material and, thus, saws blocks 202, 204, 206, 208 into thin slices. Such slices may for example be used as wafers in semiconductor industry. The total length of wire in the wire web being in contact with the material to be sawed at a time may be referred to as the effective wire cutting length. In some embodiments, the effective wire cutting length is 700 m or above, particularly the effective wire cutting length may be more than 900 m. Furthermore, the speed with which the material to be sawed is lowered into the wire web may be referred to as the material feed rate. In some embodiments, the material feed rate is in the range of 3 µm/s to 12 µm/s, typically about 5 µm/s to 7 µm/s. Due to the geometry of wire guide device 102, wire web 200 includes a first working area 210 and a second working area 220. The sawing process can be simultaneously carried out in both working areas 210, 220 so that efficiency of the sawing device 100 is improved. Furthermore, in the shown embodiment each working area 210, 220 is sufficiently large enough such that two blocks 202, 204; 206, 208 of semiconductor material can be processed in each working area 210; 220. In one embodiment, the working length of web 200 in a working area 210, 220 along the wire moving direction 215, 225 is between 500 mm to 600 mm.

[0024] The wire saw device 102 can, according to some embodiments, which can be combined with other embodiments described herein, include a further wire management unit 240 which is similar to wire management unit 230 described above. The second wire management unit 240 includes a wire supply spool 244 and a take-up spool 248. Wire supply coil 244 provides fresh wire 238 and take-up spool 248 recoils used wire 248. The first management unit 230 provides a first wire for forming a first wire web portion while the second wire management unit 240 provides a second wire for forming a second wire web portion. Thereby, it is possible that the wire guide cylinders drive both the first and second web portions so that the wire speed is identical for the first and second web portion. Furthermore, the wire transport directions of the first and second webs portions will be identical. Since second wire management unit 240 is mirrored with respect to first wire management unit 204, the wire feeding direction and wire recoil directions are reversed.

[0025] In other words, a composite web 200 is formed by the first and second web portions wherein the composite web is continuous in its properties so that there is no difference to a single web with respect to the cutting process. In particular, composite web 200 is adapted for cutting the blocks of semiconductor material. Embodiments including a composite web 200 formed from separate wire web portions are advantageous in that the wire length of one web in a working area 210, 220 is only half of the length compared to a single wire web. When using the same amount of wire in the wire reservoir, the wire length which can be utilized for sawing is doubled.

[0026] Generally, when operating a wire saw device motors, drives, as well as further moving parts need to be controlled. According to embodiments, which are described with respect to FIG. 3, a wire saw device 300 is provided. Within the wire saw device, there is a wire management unit. The wire management unit includes a spool 312 having a spool shaft 310 and a rotation axis. The spool is carried by the spool shaft 310. The spool shaft 310 is rotatably mounted to the main frame portion 301 for rotation around a spool axis. Thereby, the spool shaft 310 rotates the spool about the spool axis. The spool shaft rotation may be driven by a spool motor. In contrast, the pulleys to be described below are generally freely rotatable. On the spool 312, wire 10 to be provided towards the wire web is carried in a wire carrying area of the spool 312.

[0027] A first pulley 320 is shown in FIG. 3. Typically, a pulley has a groove adapted for guiding the wire. Further, a pulley generally can have a wire guiding position for guiding one wire in the pulley, i.e., in the pulley groove. The first pulley 320 is adapted for receiving the

wire 10 from the spool 312, in particular directly from the spool 312, and for then redirecting the wire. The first pulley is rotatably mounted to a pulley carrying unit 324, so that the first pulley 320 rotates around the first pulley axis. The pulley carrying unit 324, in turn, is connected to the wire saw device, more specifically to a main frame portion 301 of the wire saw device 300, so that the pulley carrying unit 324 is longitudinally movable along which a pulley motion track, i.e., the pulley motion track is defined as the region along the pulley carrying unit is movable. Thereby, also a first pulley motion track for the first pulley is defined, i.e., a track along which the first pulley 320 is longitudinally movable. Further, as a general aspect, the first pulley motion track may have a length of at least 90% of the length of a wire carrying area of the spool 312. Here, the wire carrying area is the lengthwise section of the spool 312 from which the wire may emerge from the spool, i.e., generally the length from flange to flange of the spool. As a further general aspect, the pulley motion track may extend over the length of the wire carrying area, from flange to flange. The pulley motion track of pulley 320 is essentially parallel to the spool axis.

[0028] The main frame portion 301 is rigidly connected or rigidly connectable to the wire saw device chassis. Thereby, the main frame portion is very robust and, e.g., a load on the main frame portion can be absorbed by the chassis. The first pulley axis is oriented at an angle of essentially 90° with respect to the spool axis. Herein, the angle is defined as a spatial angle, i.e., the angle of the axes in the plane spanned by the axes (if necessary, after a parallel shift of one of the axes so that the axes cross and hence span a plane). The angle is defined as an absolute value, i.e., is always positive. According to embodiments which are described herein, a pulley moving device is provided. The pulley moving device is adapted to cause the pulley carrying unit to move along the pulley motion track in a bi-directional mode.

[0029] According to further embodiments, which can be combined with other embodiments described herein, a wire position detection device 326 can be provided. The wire position detection device detects the wire position along the direction of the motion path (here: along the spool axis), more particularly it detects at which wire position the wire traverses a detection region of the wire position detection device 326. Thereby, the position at which the wire leaves the spool 312 or the wire carrying area can be obtained (if necessary by triangulation).

[0030] The wire management unit of Fig. 3 has a second pulley 330, which is adapted for receiving the wire from the first pulley 320, in particular directly from the first pulley, and for redirecting the wire. The second pulley 330 is rotatably mounted to the main frame portion

301 for rotation around a second pulley axis. Generally, within the wire management unit, further pulleys can be provided as well. The wire can be redirected by the first pulley 320 by a first redirection angle of 90°, and by the second pulley 330 by a second redirection angle of 180°. Due to the large second redirection angle, a main portion of the wire tension, especially in the case of tension peaks, is absorbed by the second pulley which is firmly supported by the main frame portion 301.

[0031] Generally, the pulleys 320, 330 and 340 are arranged to guide the wire in predetermined planes. The pulley carrying unit 324 can be provided as a retractable or telescopic bar. The retractable or telescopic bar is longitudinally movable along a bar axis parallel to the spool axis. The bar is longitudinally movably mounted to a wall portion of the main frame portion 301, more precisely of a wall portion of a recess in a housing wall.

[0032] Further, in the embodiment of Fig. 3 the main frame portion 301 includes a mounting member, to which the second and third pulley 330, 340 are mounted. The mounting member, being part of the main frame portion, is rigidly connected to the chassis of the wire saw device. While other designs of the mounting member are possible, in the specific embodiment of Fig. 3 the mounting member is a bar, more specifically an L-shaped bar with a first leg extending to a side surface of the main frame portion (i.e., extending parallel to the x axis), and with a second leg forming an essentially right angle with the first leg and extending to a top surface of the main frame portion (i.e., extending parallel to the z axis). Independently from the shown embodiment, it is a general aspect that the first pulley 320 and the second pulley 330 (and, if present, also other pulleys such as a third and / or fourth pulley) are mounted on a common mounting member, especially on a one-piece mounting member.

[0033] As described above, a plurality of motors and drives are used to operate the wire saw device. Particularly, the wire guided cylinders are used to drive the web, the spools are used to unwind and wind the wire provided to the wire management unit, and the material to be sawed and the wire web are moved with respect to each other at a feed rate for moving the wire through with the material to be cut. According to embodiments, which can be combined with other embodiments described herein, a particularly critical operation condition during which wire breakage can occur is the stopping of the wire saw apparatus or device, that is stopping the motors and drives of the wire saw device during cutting, for example during an emergency stop. During an emergency stop a control unit of the wire saw device determines the need to stop the sawing process, for example as fast as possible. However, in light of the different inertia of pulleys, wire guided cylinders, spools, and other components of the wire

management unit or the web forming unit that guide and transport the wire, it is very difficult to slow down and stop all components at the same time. Further, re-starting a wire saw device or apparatus while the wire is within the material to be sawed might experience an increased risk of wire breakage because there is a tendency that the wire gets stuck within the material if the wire speed is not maintained until the sawing process is completed.

[0034] Thereby, it should be noted that an emergency stop is generally beneficial as compared to an uncontrolled failure of one drive or motor, which might result in damage to the wire saw device or uncontrolled behavior of the wire that would in turn significantly increase downtime of the system. Even though there might be the option of slowing down the stopping process during an emergency stop, this does still include the risk of a wire breakage during re-start of the saw while the wire is located within the material to be cut.

[0035] One event that might occur on a regular basis and which can result in determination of the need for an emergency stop is a varying grid voltage, a variation of the DC voltage generated by DC transformation of the grid voltage or variations of another physical quantity of the power supply grid, which provides power to the wire saw device. Figure 4 shows a graph 400 that illustrates the voltage, which can be a DC voltage converted from the grid power or an AC voltage in the grid, as a function of time, the voltage being provided by a grid to a wire saw device. Thereby, typical scenarios are shown in areas 402, 404, 406, and 408. In an optimum case or for a very stable grid, the voltage provided to the wire saw device can be essentially constant as shown in the area of 402. Thereby, typically the value of the grid voltage can be the nominal grid voltage or a stable average value, which is close to the nominal quick voltage. However, at many fabrication plants or in many cases, the grid voltage will not be fully stable and small deviations from the nominal or average grid value can occur. Thereby, as shown in figure 4 the curve 401 may drop below a threshold value, which is indicated by reference numeral 412. Even though the variations or deviations during the time period 402 are comparably short, the controller of a wire saw device might take these deviations as an indication of a requirement for an emergency stop. Another scenario is shown in time period 406. Thereby, a comparably small deviation from the nominal value is experienced. The deviation is sufficiently large to be below the threshold of 412 and extends over a certain (longer) period of time. The last scenario 408 of curve 400 shows a more significant voltage drop. Thereby the curve 401 drops below a second threshold value 414.

[0036] Typically, a voltage drop in the grid voltage can result in a drop in DC voltages of the system, which can be used for motors and drives. If a voltage drops, for example, by about 15

rel.-% to 40 rel.-%, such as for example 20%, of a desired value of a physical quantity malfunctioning of drives and motors might occur such that an emergency stop must be conducted before one of the drives or motors fail. Thereby, a voltage drop by 20% is to be understood as a voltage drop to 80% of the desired value. According to typical embodiments, the desired value can be a nominal value, a calculated value, an average value, and combinations thereof. According to other alternative electrical set-ups, a voltage drop in the grid voltage might be compensated for, such that the DC voltages do not drop to a significant amount. Typically, these electrical set-ups compensate the voltage drop by using more current from the grid, in order to generate a similar power output from the grid. Depending on the increase in current delivered by the grid, this might also result in electrical failure in the case that the current exceeds a level, such that an electrical cabinet, which is connected to the grid, or even an electrical installation at the manufacturing facility cannot handle the increased current. Thus, even though a DC voltage drop in the wire saw device might be compensated for, a similar problem occurs if the grid is not stable. As explained above, according to some embodiments, which can be combined with other embodiments described herein, the voltage drop of the grid voltage and/or the current provided by the grid power supply can be used as an indication of abnormality. According to further embodiments, which can be combined with other embodiments described herein, all physical quantities of a power supply grid, i.e. deviations in the voltage, the frequency, the power factor or the phase (real vs. reactive power) and existence of other overlapping harmonic frequencies on the AC voltage could trigger an event, which would normally result in an emergency stop, could initiate indication of abnormality.

[0037] Yet, as explained above, an emergency stop has an increased probability of resulting in wire breakage. According to embodiments described herein, the deviation of a value of a physical quantity of the grid from a nominal and/or average value does not directly result in an emergency stop. According to embodiments described herein, determination of such the deviation results in the reduction of one or more of the velocities of motors and drives in the wire saw apparatus. According to typical embodiments, the reduction of the wire speed and the reduction of the material feed rate, i.e. the velocity at which the material to be sawed and the wire web are moved with respect to each other, is initiated when a deviation of a physical quantity of the grid is determined.

[0038] According to typical embodiments, which can be combined with other embodiments described herein, the wire speed and the material feed rate are reduced by at least 30 rel.-%,

for example by 40 rel.-% to 70 rel.-%, e.g., 50 rel.-%. During the period of reduced speed, the controller of the wire saw device evaluates, whether a further reduction of the sawing speed, which can be reduced to result in a stop of the wire saw device, is required or whether the abnormality of the one or more physical quantities of the power supply grid is not significant enough to bring the wire saw device to a full stop. As a yet further result, an evaluation of the physical quantities of the power supply grid can find that the values of the grid have been changed back to nominal conditions such that the wire saw device can be re-accelerated to normal operation conditions.

[0039] Referring to the exemplary curve 401 of one physical quantity of the power supply grid, namely the voltage, the improved method of operating a wire saw device can be described as follows. During the time period 402, the voltage is essentially not deviating from the predetermined grid value such that the wire saw device can operate under normal conditions. During the time period 404, there are two voltage drops 422 and 424 which can be determined to be below the threshold value 412. These voltage drops can trigger detection of an abnormality. As described herein, a method of operating a wire saw apparatus or device can thus be conducted at a reduced speed on occurrence of these voltage drops. However, these voltage drops are relatively short and the grid voltage increases back to an essentially nominal value after the voltage drops.

[0040] Accordingly, the wire saw device can be reduced in speed, when the voltage drop 422 is detected and can return to normal operation, that is full speed, after the voltage has increased again. Thereafter, when the voltage drop 424 is detected the speed of the wire saw device is again reduced and after the voltage drop 424, the wire saw device can return to normal operation. During time period 406, the voltage drop 426 is also below the threshold 412. Accordingly, when the curve drops below the threshold, the wire saw is reduced in speed. In light of the fact that the voltage drop extends over a certain period of time, the wire saw operation process can decide after a determined time period that the wire saw has to change from the reduced speed mode to a full stop after a certain time. A similar reaction can result from the voltage drop 428 in time period 408. Thereby, when the voltage drop is determined to be below the threshold 412, the wire saw is reduced in speed. Thereafter, when that deviation is further determined to be below the threshold 414, the wire saw is brought from the reduced speed to an emergency stop situation. In light of the above, an emergency stop can, for example be completely avoided for the two voltage drops 422 and 424. Even though an emergency stop might be conducted for voltage drops 426 and 428, as described

above, the emergency stop might in some cases not be conducted from a normal operation mode, i.e. a full speed mode, but the emergency stop is conducted starting from the mode of reduced sawing speed. Accordingly, even though an emergency stop might still occur, the probability of wire breakage can also be reduced in these cases.

[0041] According to another example, the voltage drop 428 can result in the following operation conditions. As shown in FIG.4, the voltage can increase to a value close to the desired value after the drop. As described above, the wire saw device has performed an emergency stop due to the voltage drop. If the power supply has returned to desired or normal values after the power stop, the wire saw device can detect the normal values and can automatically re-start normal operation. However, it is also possible that the voltage switches off completely (not shown in FIG. 4). In such a case a regular start of the wire saw device can be performed after power is again available thereafter.

[0042] Accordingly, the system goes into a preventive state or a safe mode of operation when a voltage drop or another deviation of a physical quantity of the electrical network, i.e. the grid power supply, does occur, for example, in a plant for photovoltaic wafer manufacturing. Typically, when the DC voltage provided for motors and drives reaches the value below critical level, for example about 97% to 80% of the nominal value, the wire saw device goes into a safe mode of operation, where the electrical components controlling the process such as the wire speed, the table speed, the slurry flow, heating means, cooling means or other electrical components, switch to the about 40% to 60% of the normal operation values. Thereby, the reduced speed of the moving portions, particularly the wire speed and the table speed, reduce the risk of wire breakage and allow for easier emergency stop if this might be desired. Reducing the power used for other process parameters, such as essentially all electrical consumers, for example wire speed, the table speed, the slurry flow, and heating means, cooling means, reduces the current used for an active DC converter, which would use an increased current in the event of an AC voltage drop in order to obtain the same DC voltage.

[0043] For example, if the normal operation corresponds to a wire speed of 15 m/second and 400 microns/minute table speed, the device can switch to 7 to 8 m/s wire speed and 150 to 250 microns/min table speed. Thereby, according to embodiments described herein, the wire saw device can continue operating for a few seconds in a safe mode during which the voltage drop might disappear. As long as the deviations do not reach a critical level, for example about 30% to 70% of the nominal values, and/or the deviations do not occur over a long

period of time, for examples more than 5 s, 10 s or 30 s, the equipment can continue operation. If the deviation of the value of the physical quantity of the grid continues to exist and/or reaches a critical level, the system can proceed with an emergency stop. If the physical quantity of the grid continues to a normal level, then the system can return to its normal operating mode.

[0044] According to different embodiments, which can be combined with other embodiments described herein, the determination or evaluation of deviations can be conducted based on a threshold, based on a threshold and a time, or based on the product of threshold and time. In the latter case, a relatively small deviation could result in triggering an abnormality if it extends over a correspondingly longer time period. Further, the level, which results in an emergency stop can be a fixed level, which would result in a stop after an internal DC voltage, which has been converted from the AC power supply (the grid or network), or another quantity of the grid or network experiences a deviation from a nominal value, i.e., a desired value. For the emergency stop this can typically be a fixed deviation from a fixed value, e.g. a drop by 20 % of the DC voltage. Yet, the threshold or another criterion for operating the wire saw device can be a voltage drop by e.g. 5% of a desired value, which can be a calculated value. Thus, contrary to the emergency stop value, the safety mode value can be a floating desired value, which takes into account the grid stability over time. For example, if the average grid voltage slowly but continuously decreases over time, the threshold for the safety mode can be a drop by 3% to 10% of the continuously decreasing voltage. Particularly in regions with instable grids, this might result in an operation condition where the safety mode threshold has continuously decreased such that the safety mode threshold has dropped below the emergency stop threshold. In such a case, the wire saw device could conduct an emergency stop without a previous safety mode operation.

[0045] Embodiments of the present invention allow the wire saw device to go into a safe mode when a voltage drop or the like occurs in the electrical network (the grid) of the plant and prevents the equipment to stop for other reasons than mature power failures.

[0046] Figure 5 illustrates embodiments of a wire saw device 500, which are adapted for the operation methods described herein. The wire saw device 500 includes a housing 502 and an electrical cabinet 510. The electrical cabinet 510 can be separated from the housing 502 or it can be fully or partly integrated into housing 502. The power supply 503 is connected to the electrical cabinet 510. The power supply can be an electrical connection in the plant or the fabrication system, which provides power to the wire saw device from an electrical network

or a grid, such as a public electrical network, an internal grid, or the like. As indicated by that miniaturized copy of graph 400 next to the power supply 503, variations and deviations of physical quantities of the grid are fed into the wire saw device 500. For example, in the electrical cabinet 510, a measuring unit 512 for measuring values of physical quantities of the power supply is provided. Thereby, the measuring unit 512 can determine variations and deviations of desire values of the physical quantity of the power supply. If a deviation is determined to be above a deviation, which has to be considered as normal, the measurement unit having an output for outputting a signal to an input of a control unit 514, sends a signal to the control unit 514. The measuring unit and/or the control unit 514 can evaluate the deviations and correspondingly send a signal from the output of the control unit 514 to an input of the drives and motors 522 and 524, respectively, to reduce the operation speed thereof.

[0047] According to yet further embodiments, which can be combined with other embodiments described herein, the measuring unit 512 could additionally or alternatively also measure the DC voltage provided within the wire saw device 500 based upon the grid power supply. According to yet further alternative embodiments, the measuring unit 512 and the control unit 514 may also be provided within the housing 502 of the wire saw device and does not necessarily need to be located in an electrical cabinet 510. The measuring unit can be separated or integrated into an electrical converter, an electrical inverter, or the like.

[0048] Figure 6 illustrates in further embodiments of operating a wire saw device. In step 602, the wire saw device is operated under normal conditions. Thereby, values of one or more physical quantities of a power supply grid are measured. If in step 604 essentially no deviation from a desired value of a physical quantity is detected or determined, the wire saw device continues to operate under normal conditions (step 604 = "no"). Thereby, according to some embodiments, which can be combined with other embodiments described herein, essentially no deviation is to be understood to include small deviations, which are common to a normal status of the power supply. In other words, determining deviations (yes in step 604) can be understood such that the value of the physical quantity deviates from the desired value, nominal value, calculated value and/or an average value to a certain degree. Thereby, such a deviation can be for example a drop by 3% to 15% or 5% to 10%, e.g. 5%, from that desired value of the physical quantity of the power supply grid. According to yet further embodiments, which can be combined with other embodiments described herein, the physical quantity can be at least one physical quantity selected from the group consisting of: a voltage

(DC or AC), a frequency, a power factor, and harmonics of a frequency. Thereby, typically a voltage can be used as the physical quantity. According to alternative modifications, the voltage can be a grid voltage supplied to the wire saw device and/or an internal voltage within the wire saw device, such as the DC voltage.

[0049] If a deviation as described herein is determined, the wire saw device operates in a safe operation mode in step 606. Thereby, according to typical embodiments, which can be combined with other embodiments described herein, the sawing speed of the wire saw device is reduced. For example, one or more of the velocities of drives or motors can be reduced to about 30% to 70%, e.g. 50%, of the respective speed during normal operation. According to some embodiments, the velocities of drives or motors can be selected from the group consisting of: the wire speed, the material feed rate, the speed of a wire tracking system, and combinations thereof.

[0050] Thereby, according to yet further embodiments, a wire tracking system is referred to a wire management unit adapted for a wire saw device having a wire forming a wire web for cutting. Thereby, the wire management unit includes a pulley moving device; at least one pulley for redirecting the wire and adapted for guiding the wire to the wire web, wherein the at least one pulley is connected to the pulley moving device and is adapted to rotate around a pulley axis; a spool for providing a wire towards the wire web during unwinding of the wire from the spool, wherein the spool includes a rotation axis and a wire carrying area with a length along the direction of the rotational axis; and wherein the pulley moving device is adapted to move the at least one pulley along the direction of the rotation axis. According to some embodiments, which can be combined with other embodiments described herein, the controller can have a CPU and memory such that a self-learning process for tracking the wire position can be implemented. Thus, a spool-pitch teach-in capability can be provided for some embodiments.

[0051] During operation, in a normal operation mode and in safe operation mode, the wire saw device continues to measure values of at least one physical quantity correlating to one or more physically quantities of the power supply grid. Accordingly, determination of a deviation of such a value from a nominal value is evaluated in step 608. If the previous deviation disappeared, the wire saw device can return to normal operation in step 602. Thereby, the drives and motors, which have been operating at reduced velocities during the safe operation mode, are accelerated to return to a normal operation sawing speed. If the deviation still exists but has not reached a critical value sufficiently high enough to trigger an

emergency stop, the wire saw device continues to operate in the safe operation mode in step 606. If the deviation has further increased and/or has been existent for a certain time period, step 608 determines a yes and stops the wire saw device in step 610.

[0052] According to different embodiments, which can be combined with other embodiments described herein, a critical deviation for triggering an emergency stop can be a deviation from a desired value by at least 25% to 75%, such as 20 % or 35%. Thereby, a deviation by, e.g., 20% of the desired value is to be understood as a deviation to 80% of the desired value. Additionally or alternatively, a critical deviation triggering an emergency stop can be a deviation for triggering the safe operation mode in the event that this deviation occurs for a time of at least 3 seconds, 5 seconds, 15 seconds, and above.

[0053] Figure 7 illustrates yet further embodiments of operating a wire saw device. After the wire saw device has started in step 702, it is, in step 704, operated under normal conditions. Thereby, values of one or more physical quantities of a power supply grid are measured. Typically a voltage drop of the grid voltage and/or of a resulting DC voltage in the wire saw device is measured. If in step 706 essentially no deviation from a predetermined voltage is detected, the wire saw device continues to operate under normal conditions. Thereby, according to some embodiments, which can be combined with other embodiments described herein, essentially no deviation is to be understood to include small deviations, which are common to a normal status of the power supply. In other words, determining deviations (yes in step 604) can be understood such that the value of the physical quantity deviates from the desired value, e.g., a calculated value, a nominal value and/or an average value by at least 5% of the desired value. Thereby, such a voltage drop can be, for example, a voltage reduction by 3% to 15% or 5% to 10%, e.g. 5%, from the desired voltage value. According to yet further embodiments, which can be combined with other embodiments described herein, the slope(s) of physical quantities over time can be determined. Thereby, if the slope of a voltage drop exceeds a certain value, i.e. the voltage drops very fast, triggering of a safety mode operation or an emergency stop can also be provided.

[0054] If a deviation as described herein is determined, the wire saw device operates in a safe operation mode in step 708. Thereby, according to typical embodiments, which can be combined with other embodiments described herein, the sawing speed of the wire saw device is reduced. For example, one or more of the velocities of drives or motors can be reduced to about 30% to 70%, e.g. 50%, of the respective speed during normal operation. According to some embodiments, the velocities of drives or motors can be selected from the group

consisting of: the wire speed, the material feed rate, the speed of a wire tracking system, and combinations thereof. During operation, in a normal operation mode and in safe operation mode, the wire saw device continues to measure the voltage, such as the power supply grid voltage and/or a DC voltage. Accordingly, determination of a deviation of such a value from a nominal value is evaluated in step 710. If the previous deviation disappeared, the wire saw device can return to step 706 and can thereby return to step 704, i.e. to a normal operation mode. If the deviation still exists but has not reached a critical value (< y%) sufficiently high enough to trigger an emergency stop, the wire saw device continues to operate in the safe operation mode by proceeding to step 708 via step 706. If the deviation has further increased and/or has been existent for a certain time period, step 710 determines a "no" and conducts an emergency stop of the wire saw device in step 712. After stopping, the system determines the system status in step 714 and can either restart the wire saw device in step 702 or can request maintenance if desired by continuing to step 716.

[0055] Figure 8 illustrates yet further embodiments of a wire saw device 500, which are adapted for the operation methods described herein. The wire saw device 500 includes a housing 502 and an electrical cabinet 510. The power supply 503 is connected to the electrical cabinet 510. The power supply can be an electrical connection in the plant or the fabrication system, which provides power to the wire saw device from an electrical network or a grid, such as a public electrical network, i.e. a public grid, an internal grid, or the like. As indicated by that miniaturized copy of graph 400 next to the power supply 503, variations and deviations of physical quantities of the grid are fed into the wire saw device 500. For example, in the electrical cabinet 510, a measuring unit 512 for measuring values of physical quantities of the power supply is provided. Thereby, the measuring unit 512 can determine variations and deviations of desired values of the physical quantity of the power supply. If one or more deviations are determined to be above deviations, which have to be considered as normal, the measurement unit having an output for outputting a signal to an input of a control unit 514, sends a signal to the control unit 514. The measuring unit and/or the control unit 514 can evaluate the deviations and correspondingly send a signal from the output of the control unit 514 to an input of the drives and motors 522, 524, 822 and 824, respectively, to reduce the operation speed thereof.

[0056] As shown in Fig. 8, according to typical embodiments, the control unit can have a memory 841, a CPU 842, and a data receiving portion 843, like a hard drive, a CD-ROM drive, a network connection portion, a user interface, or the like. Thereby, deviations can be

calculated in the CPU; the memory can be used to store previous, average and/or nominal values of physical quantities and values of operation parameters for the drives and motors; and the data receiving portion can be used for receiving program codes or other external operations. Accordingly, according to embodiments described herein, a computer program product or software can be provided, which is adapted to operate a wire saw device according to any of the embodiments described herein, and/or which can conduct any of the improved methods according to any of the embodiments described herein, when run on a computer.

[0057] In light of the above a plurality of embodiments has been described. According to one embodiment, a method of operating a wire saw device is provided. The method includes operating the wire saw device at a first set of predetermined parameters, the parameters including a first wire speed of a sawing wire, measuring values of one or more physical quantities being a physical quantity of the power supply grid providing power to the wire saw device or a DC converted voltage of the power supply grid, determining one or more deviations of respective values of the one or more physical quantities from desired values of the physical quantities, and operating the wire saw device at a second wire speed smaller than the first wire speed depending on the determined one or more deviations. According to typical alternative or additional modifications thereof the physical quantities can be at least one physical quantity selected from the group consisting of: a grid voltage, a grid frequency, a grid phase, a power supply current, a power factor of the grid, harmonics of the grid frequency, a DC voltage resulting from a DC conversion of the grid power, and combinations thereof; the operating at the second wire speed can be conducted if the one or more deviations exceed a predetermined threshold level; the one or more physical quantities can be a voltage and the threshold deviation is a deviation by 3 rel.-% to 20 rel.-% of the desired values, wherein the threshold deviation can be different or the same in the case the threshold deviation corresponds to a voltage raise as compared the case where the threshold deviation corresponds to a voltage drop; and/or the desired values of the physical quantities can be selected from the group consisting of: nominal values, a calculated value, an average values, and combinations thereof. According to yet further alternative or additional modifications, the method can further include stopping operation of the wire saw device if the one or more of the deviations exceed one or more of the criteria of the group consisting of: a predetermined magnitude; a predetermined time period; and combinations thereof, for example, wherein the predetermined magnitude of the deviation can be at 10 rel.-% or more, typically 30 rel.-% to 60 rel.-% of the desired value. Further alternative or additional modifications can be that the difference between the first wire speed and the second wire speed can depend on the value of

the one or more deviations, particularly wherein the difference between the first wire speed and the second wire speed is proportional to the value deviation and/or the wire can be a coated wire, particularly has a diamond coating.

[0058] According to another embodiment, a computer program product having a program code, which is provided on a machine readable medium or in a memory of a controller of a wire saw device, adapted for conducting a method according to any of the embodiments described herein when operated on a computer or the controller of the wire saw device.

[0059] According to a yet further embodiment, a wire saw apparatus having a wire for forming a wire web is provided. The wire saw device includes an electrical connector adapted to connect the wire saw device to a power supply grid, a measuring unit adapted to measure values of one or more physical quantities being a physical quantity of the power supply grid or a DC converted voltage of the power supply grid providing power to the wire saw device, and a control unit being operatively connected to the measuring unit and adapted for measuring one or more deviations of respective values of the one or more physical quantities from desired values of the physical quantities of the power supply grid, wherein the control unit is adapted to operate the wire saw device in a safe operation mode. According to typical alternative or additional modifications thereof the measuring unit can have a signal output, the control unit has a signal input adapted for receiving a signal originating from the signal output of the measuring unit; the device can further include at least one drive or motor for operating a component of the wire saw device, wherein the at least one drive or motor has a signal input adapted for receiving a signal originating from the control unit and/or can further include a computer program product according to embodiments described herein. According to yet further alternative or additional modifications thereof the control unit and/or the measuring unit can be integrated in the at least one drive or motor.

[0060] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. A method of operating a wire saw device, comprising:

operating the wire saw device at a first set of predetermined parameters, the parameters including a first wire speed of a sawing wire;

measuring values of one or more physical quantities being a physical quantity of the power supply grid providing power to the wire saw device or a DC converted voltage of the power supply grid;

determining one or more deviations of respective values of the one or more physical quantities from desired values of the physical quantities; and

operating the wire saw device at a second wire speed smaller than the first wire speed depending on the determined one or more deviations.

2. The method according to claim 1, wherein the physical quantities being at least one physical quantity selected from the group consisting of: a grid voltage, a grid frequency, a grid phase, a power supply current, a power factor of the grid, harmonics of the grid frequency, a DC voltage resulting from a DC conversion of the grid power, and combinations thereof.

3. The method according to any of the preceding claims, wherein the operating at the second wire speed is conducted if the one or more deviations exceed a predetermined threshold level.

4. The method according to claim 3, wherein the one or more physical quantities is a voltage and the threshold deviation is a deviation by 3 rel.-% to 20 rel.-% of the desired values, wherein the threshold deviation can be different or the same in the case the threshold deviation corresponds to a voltage raise as compared the case where the threshold deviation corresponds to a voltage drop.

5. The method according to any of the preceding claims, wherein the desired values of the physical quantities are selected from the group consisting of: nominal values, a calculated value, an average values, and combinations thereof.

6. The method according to any of the preceding claims, further comprising:

stopping operation of the wire saw device if the one or more of the deviations exceed one or more of the criteria of the group consisting of: a predetermined magnitude; a predetermined time period; and combinations thereof.

7. The method of claim 6, wherein the predetermined magnitude of the deviation is at 10 rel.-% or more, typically 30 rel.-% to 60 rel.-% of the desired value.

8. The method of any of the preceding claims, wherein the difference between the first wire speed and the second wire speed depends on the value of the one or more deviations, particularly wherein the difference between the first wire speed and the second wire speed is proportional to the value deviation.

9. The method of any of the preceding claims, wherein the wire is a coated wire, particularly has a diamond coating.

10. A computer program product having a program code, which is provided on a machine readable medium or in a memory of a controller of a wire saw device, adapted for conducting a method according to any of claims 1 to 9 when operated on a computer or the controller of the wire saw device.

11. A wire saw apparatus having a wire for forming a wire web, the wire saw device comprising:

an electrical connector adapted to connect the wire saw device to a power supply grid;

a measuring unit adapted to measure values of one or more physical quantities being a physical quantity of the power supply grid or a DC converted voltage of the power supply grid providing power to the wire saw device; and

a control unit being operatively connected to the measuring unit and adapted for measuring one or more deviations of respective values of the one or more physical quantities from desired values of the physical quantities of the power supply grid, wherein the control unit is adapted to operate the wire saw device in a safe operation mode.

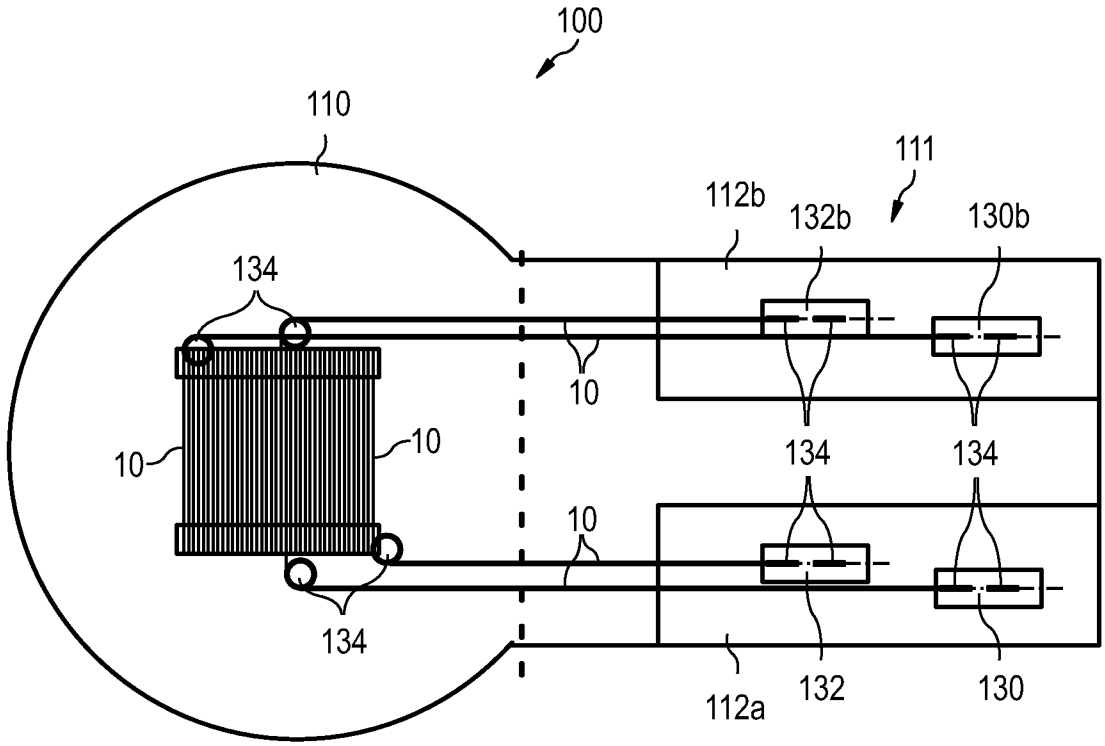
12. The wire saw apparatus according to claim 11, wherein the measuring unit has a signal output, the control unit has a signal input adapted for receiving a signal originating from the signal output of the measuring unit; and further comprising:

at least one drive or motor for operating a component of the wire saw device, wherein the at least one drive or motor has a signal input adapted for receiving a signal originating from the control unit.

13. The wire saw apparatus according to any of claims 11 to 12, further comprising a computer program product according to claim 10.

14. The wire saw apparatus according to any of claims 11 to 13, wherein the control unit and/or the measuring unit is integrated in the at least one drive or motor.

FIG 1


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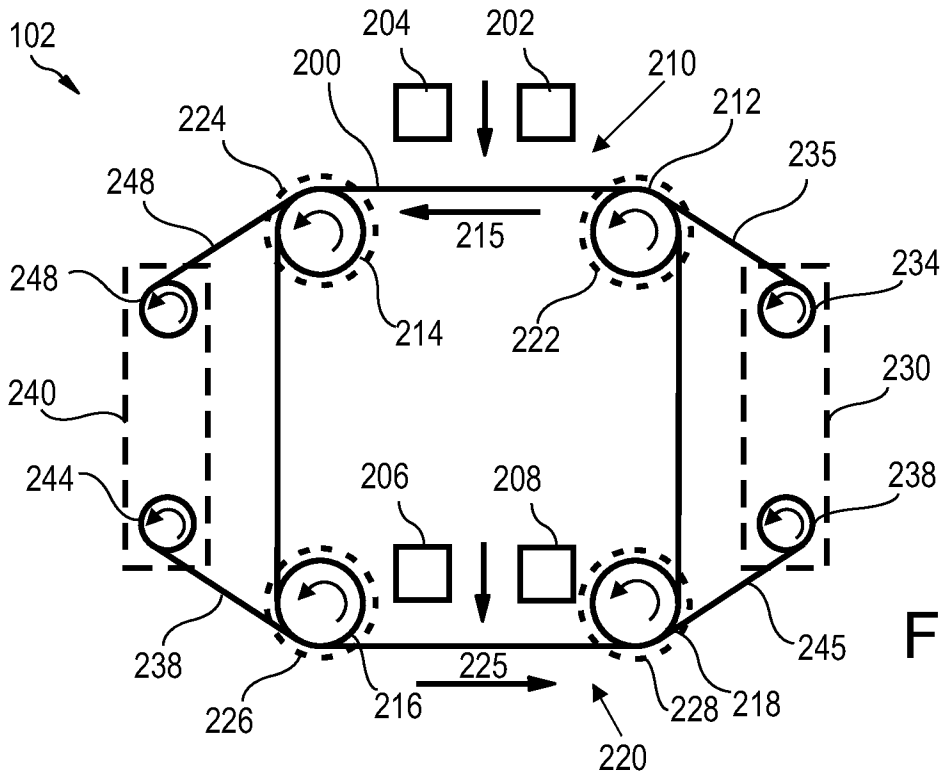

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FIG 2

FIG 3

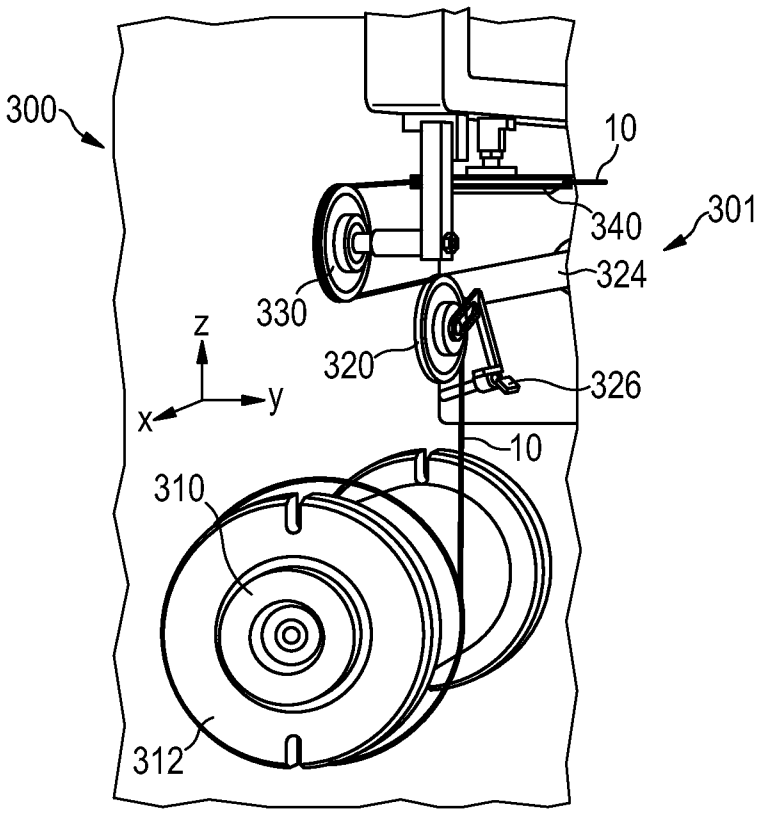


FIG 4

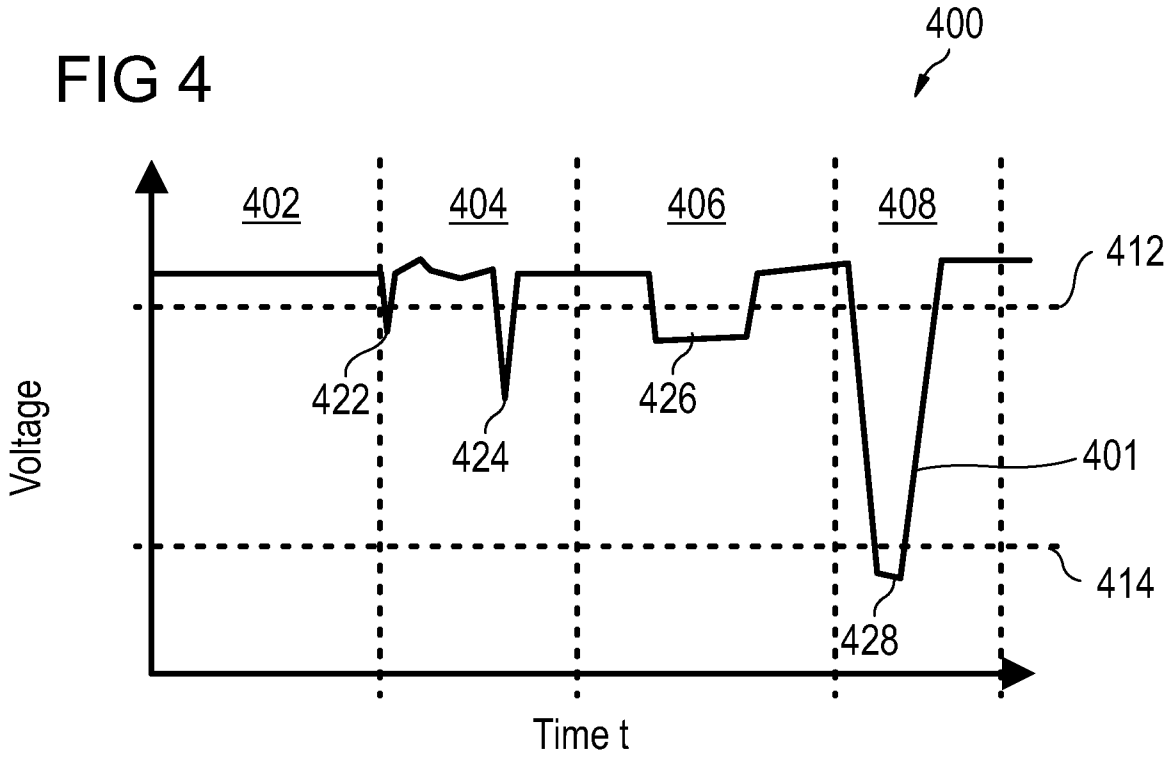
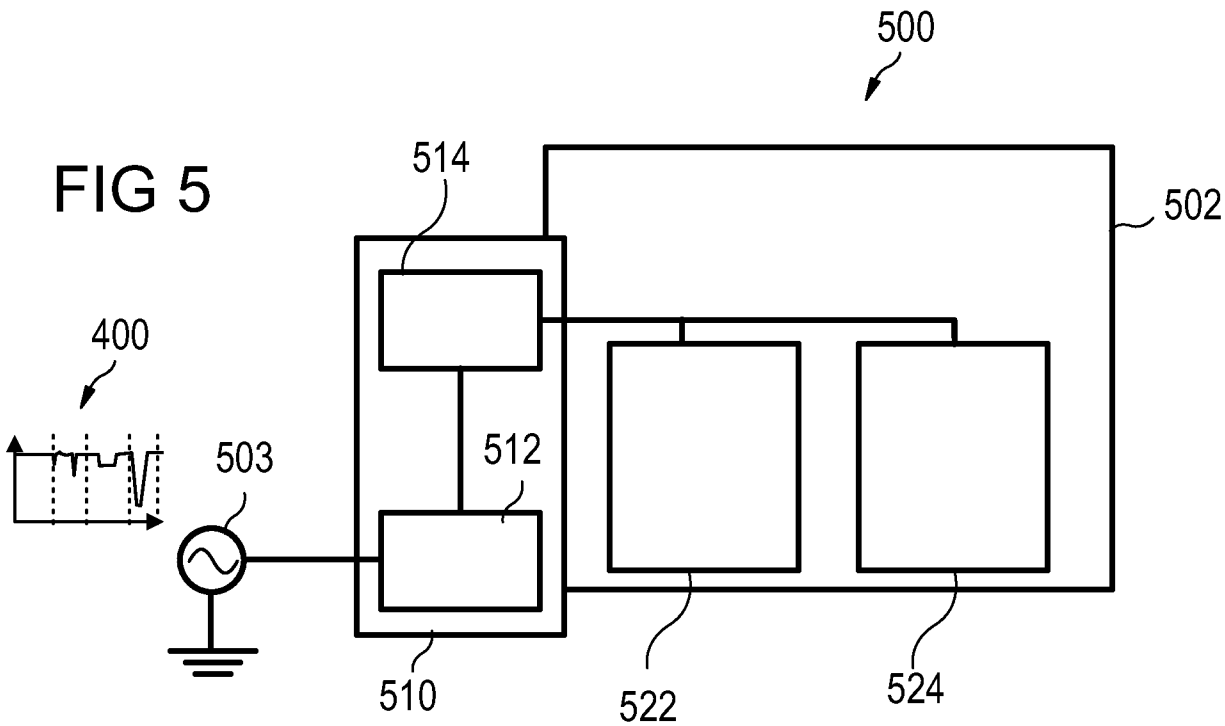

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Voltage
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FIG 5


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524

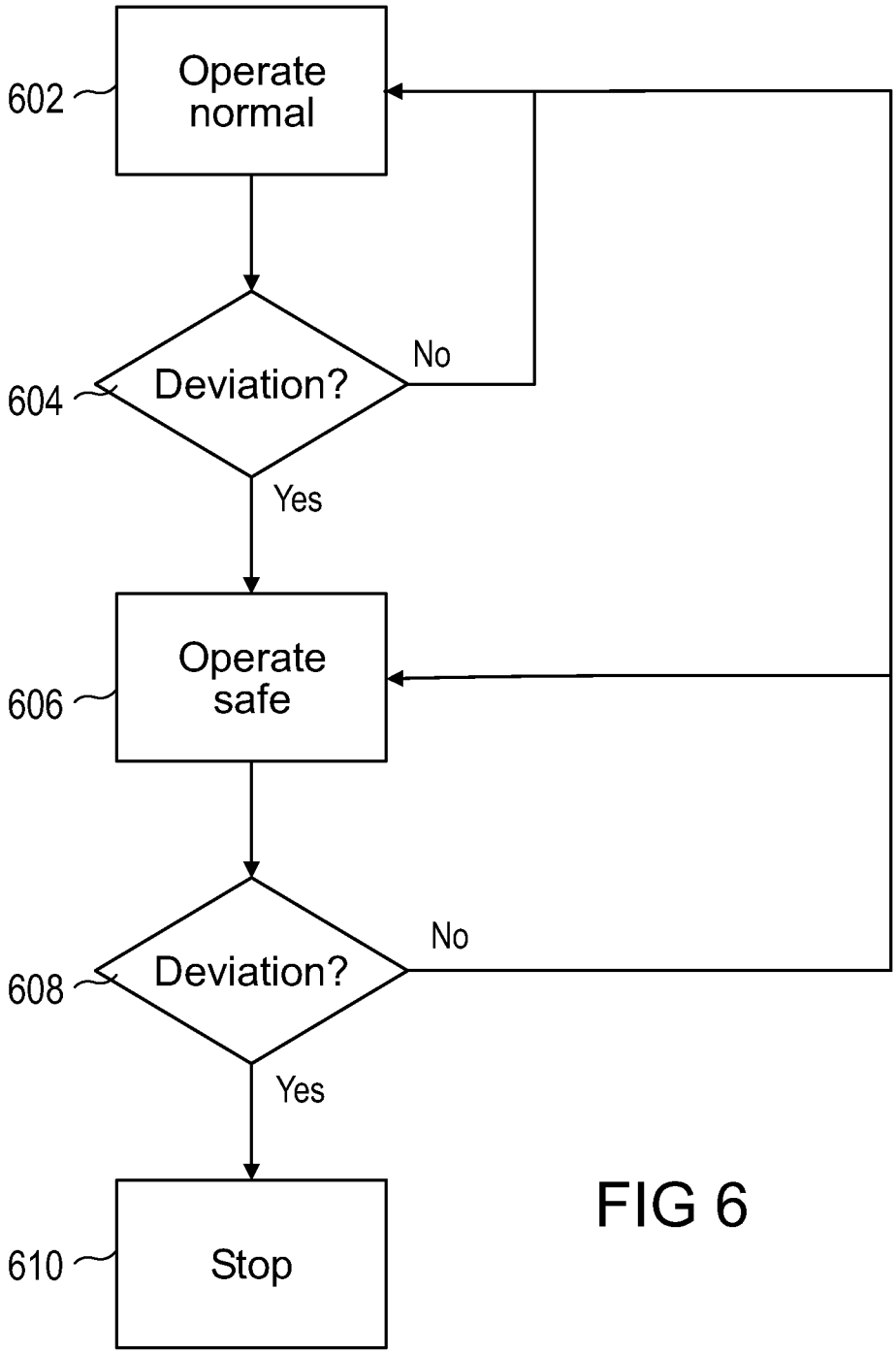
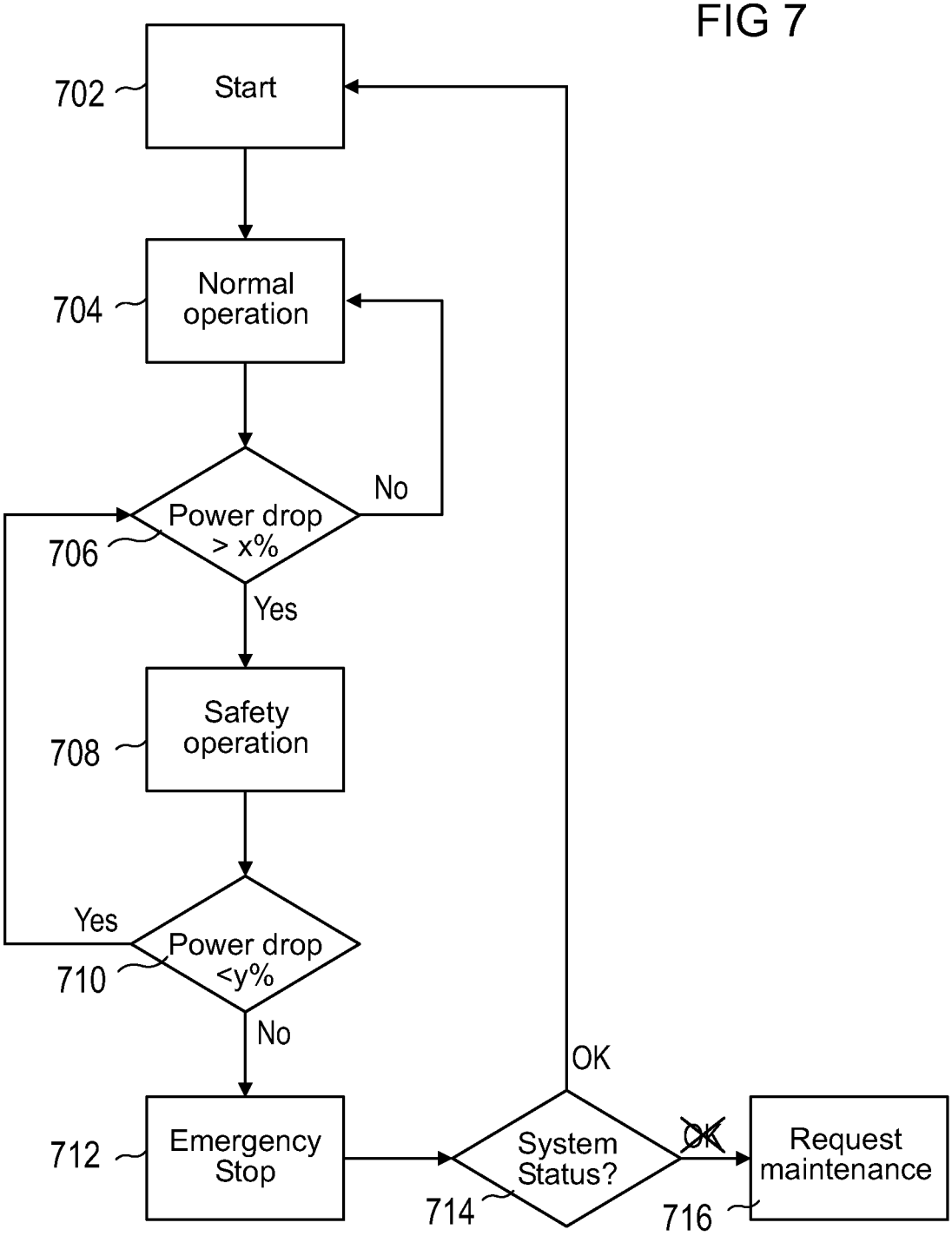

602
Operate normal
604
Deviation?
No
Yes
606
Operate safe
608
Deviation?
No
Yes
610
Stop

FIG 6

FIG 7


Start
702
Normal operation
704
Power drop > x%
706
No
Yes
Safety operation
708
Power drop <y%
710
Yes
No
Emergency Stop
712
System Status?
714
OK
OK
Request maintenance
716

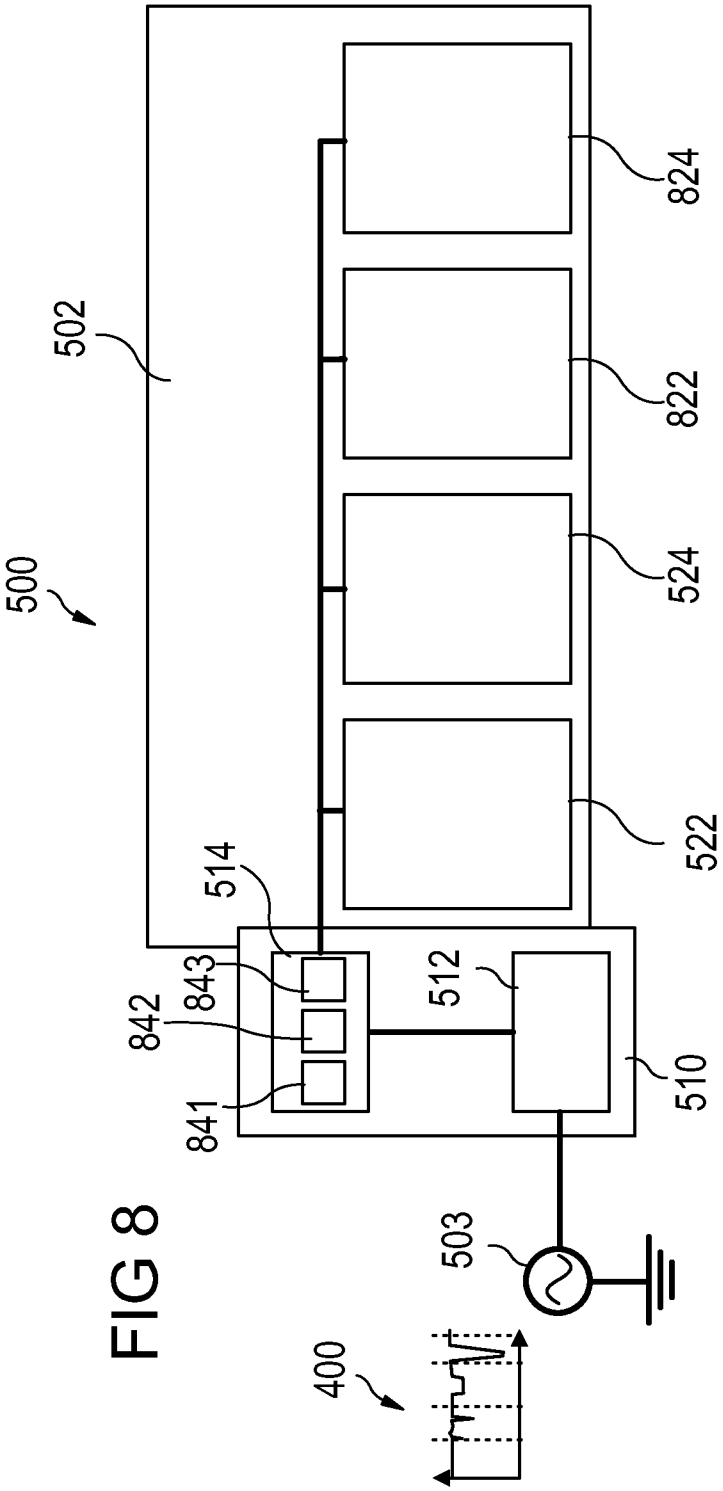


FIG 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/070809

A. CLASSIFICATION OF SUBJECT MATTER
INV. B23D57/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B23D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 947 798 A (TOYAMA KOHEI [JP]) 7 September 1999 (1999-09-07) claim 1; figures 1,2	1,11
A	EP 1 738 886 A1 (HCT SHAPING SYSTEMS S A [CH]) 3 January 2007 (2007-01-03) abstract	1,11
A	CH 696 757 A5 (HCT SHAPING SYSTEMS SA [CH]) 30 November 2007 (2007-11-30) the whole document	1-14
A	US 2 674 238 A (DESSUREAU JOSEPH T ET AL) 6 April 1954 (1954-04-06) the whole document	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2011	16/09/2011

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2010/070809

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5947798 A	07-09-1999	NONE	
EP 1738886 A1	03-01-2007	JP 2007007848 A	18-01-2007
		US 2006292712 A1	28-12-2006
CH 696757 A5	30-11-2007	NONE	
US 2674238 A	06-04-1954	NONE	