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(54) DRIVE SYSTEM FOR A FORAGE HARVESTER

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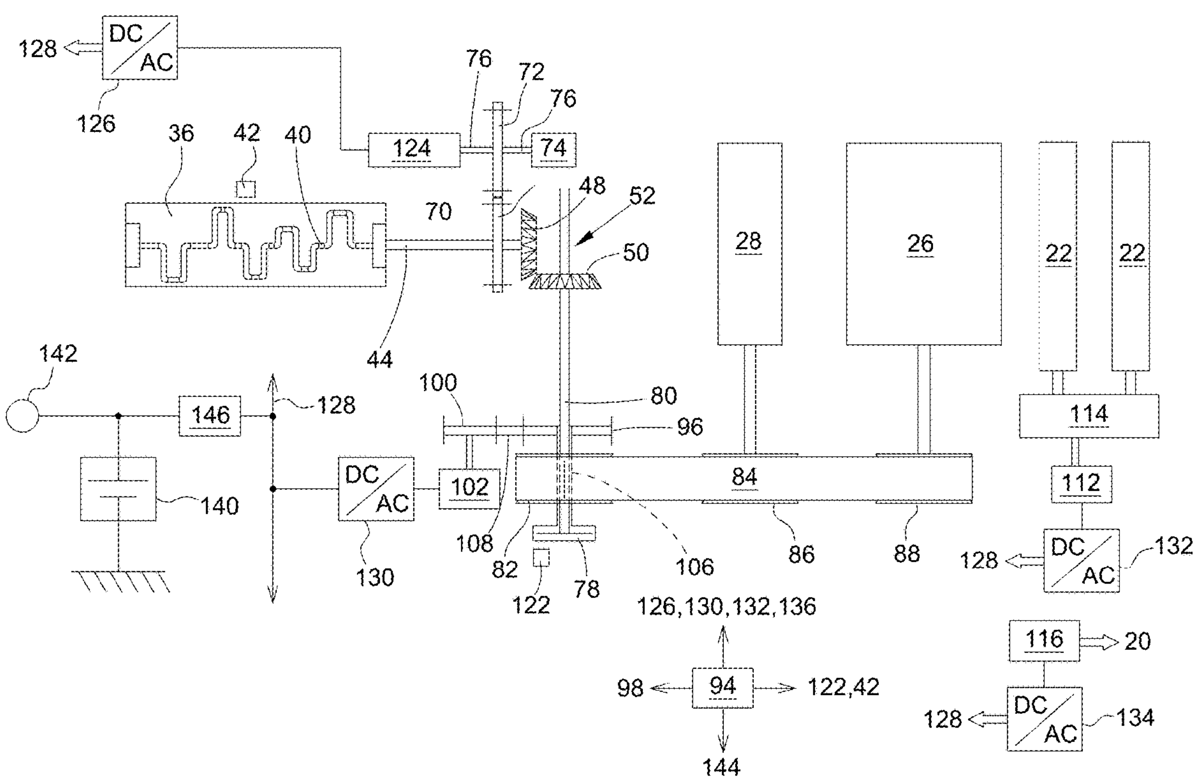
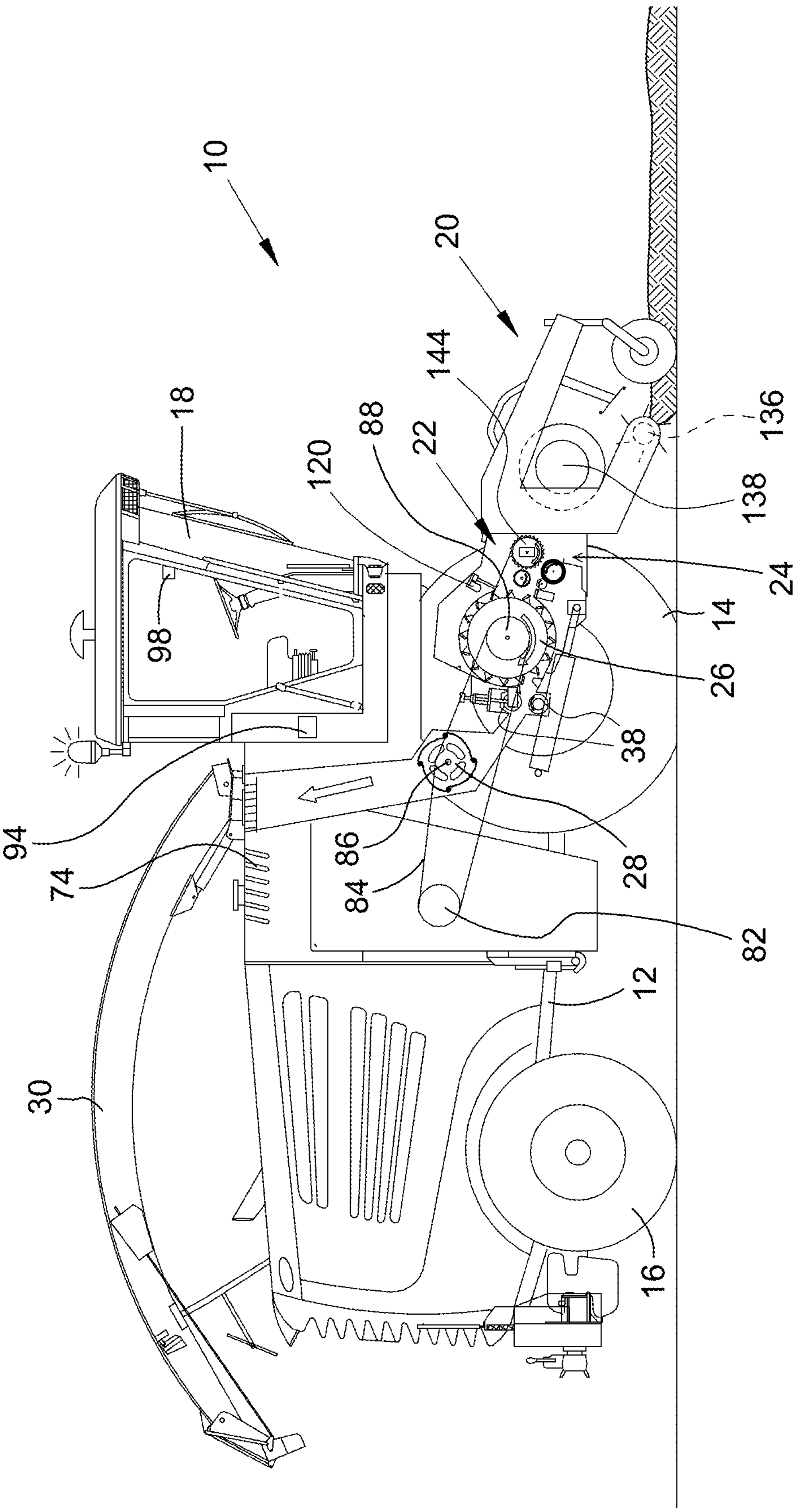
(57) **ABSTRACT**

A drive system for a self-propelled agricultural machine includes a power store, e.g., a battery, a DC-DC converter connecting the power store to a DC bus, and an electric motor connected to the DC bus via an inverter. A first cooling circuit circulates a cooling liquid for dissipating heat from the power store. A second cooling circuit circulates a refrigerant for dissipating heat from the cooling liquid of the first cooling circuit. A third cooling circuit dissipates heat from the refrigerant of the second cooling circuit, the DC-DC converter, and the inverter.




10
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18
144
136
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FIG. 1

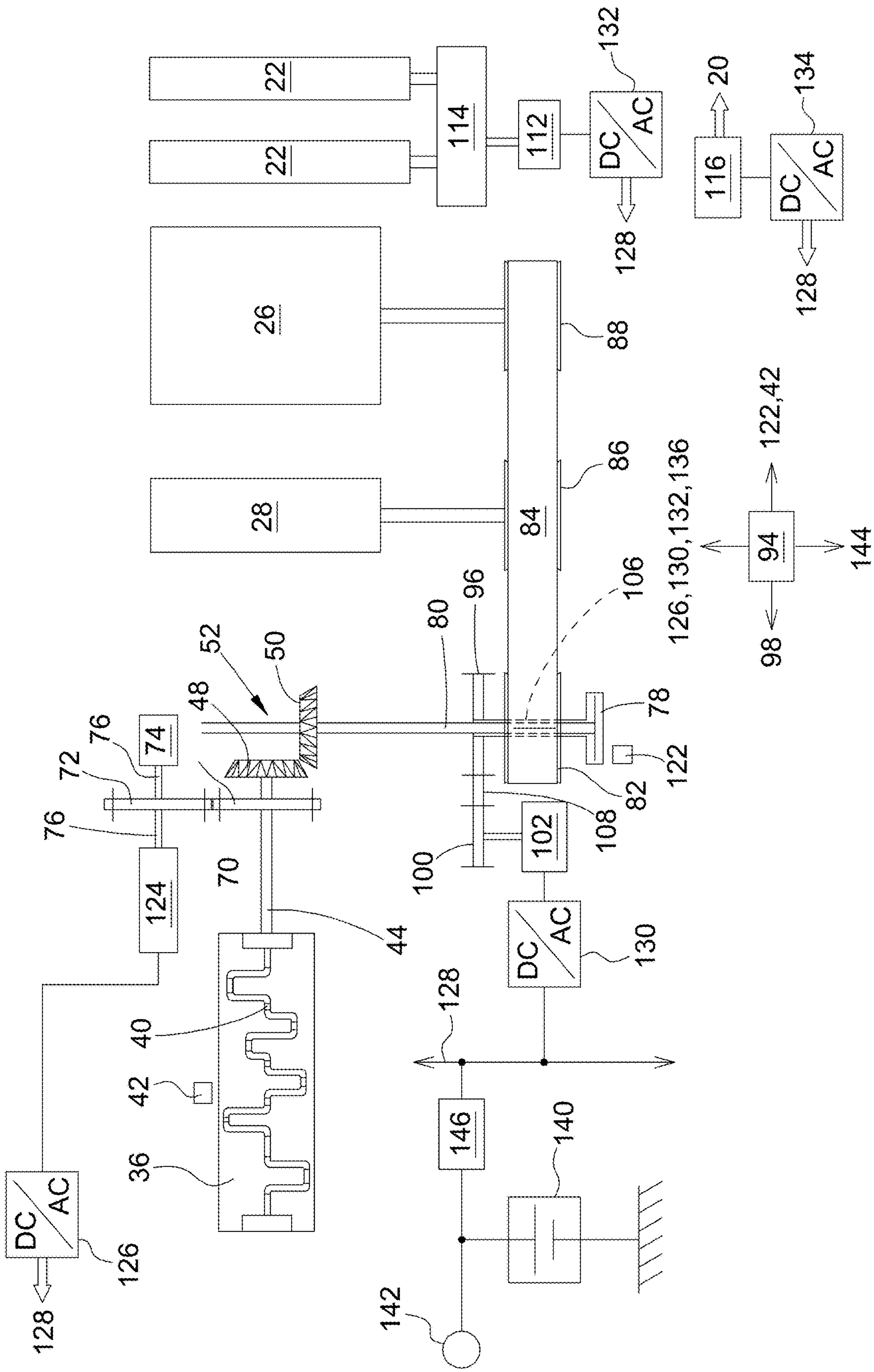
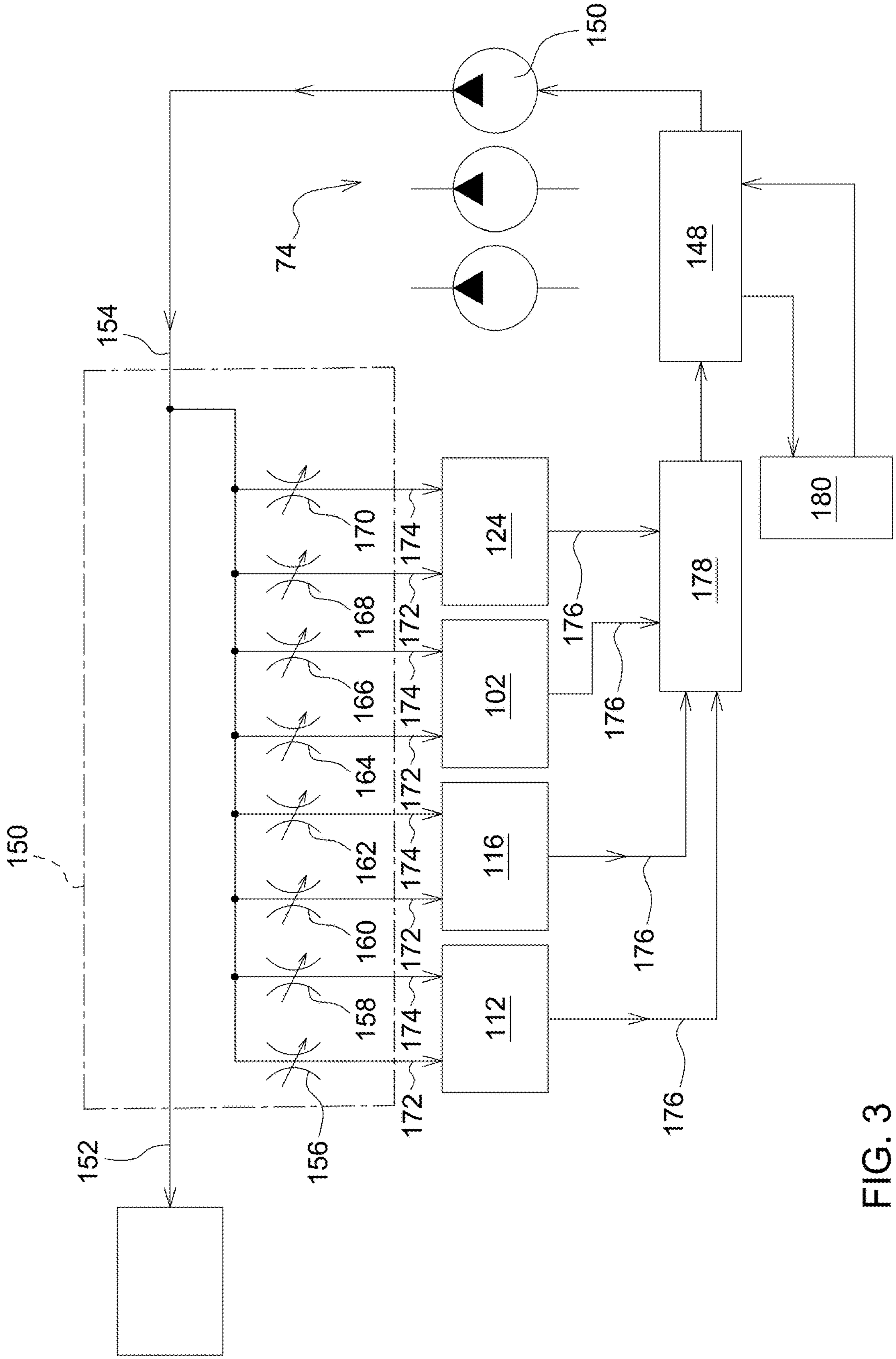

22
22
114
112
DC/AC
132
20
116
DC/AC
134
128
128
26
88
28
84
86
122,42
126,130,132,136
94
144
98
106
96
80
52
50
48
74
76
72
76
78
122
82
108
102
100
70
124
44
DC/AC
130
128
40
42
36
146
140
DC/AC
126
128
142

FIG. 2


150
74
148
154
180
124
178
102
116
112
150
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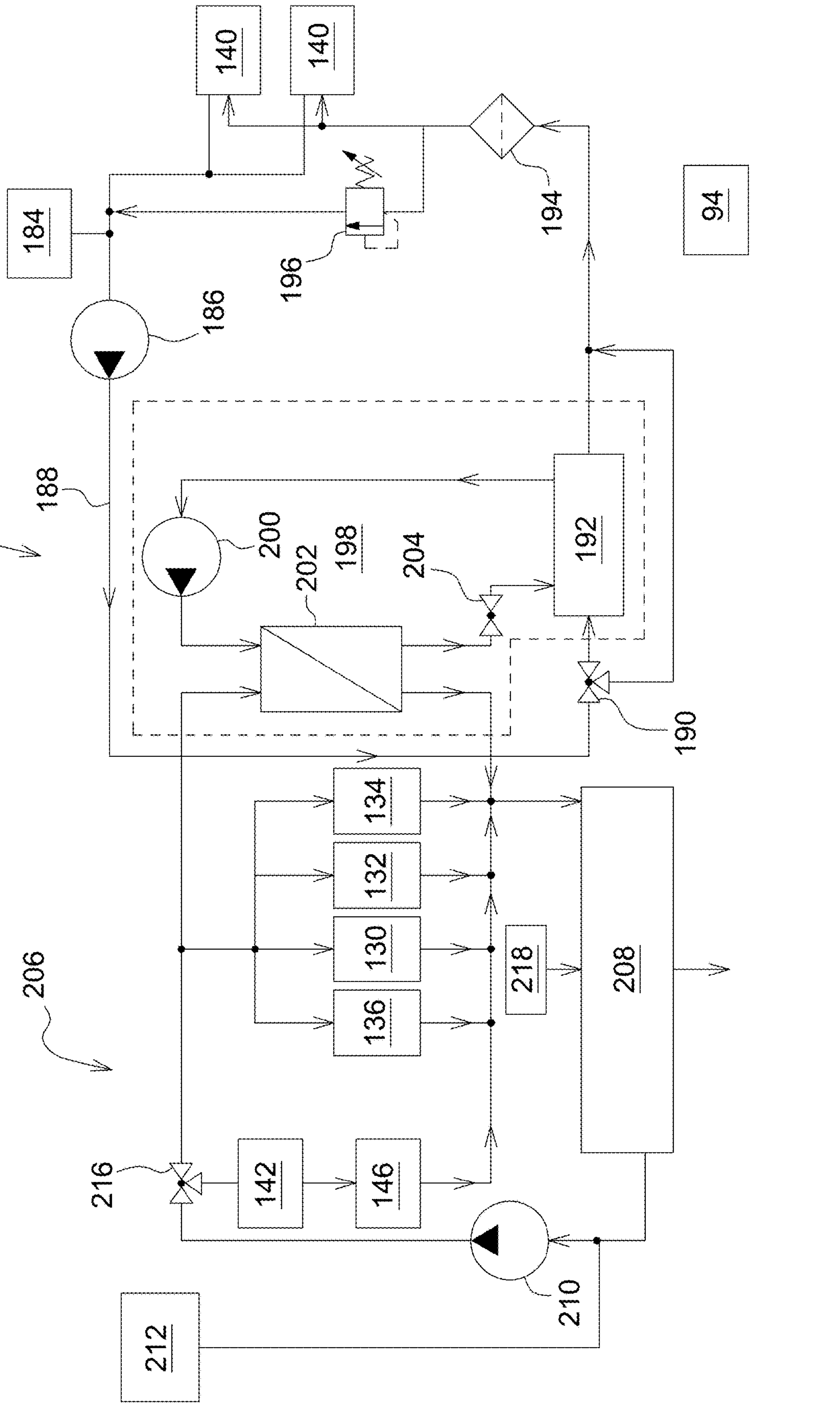
174
176

FIG. 3


140
140
184
194
196
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94
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216
142
146
210
212

FIG. 4

DRIVE SYSTEM FOR A FORAGE HARVESTER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of European Patent Application No. EP24156895.5, filed on Feb. 9, 2024, the disclosure of which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] The disclosure generally relates to a drive system for a self-propelled agricultural machine, such as but not limited to a forage harvester.

BACKGROUND

[0003] Self-propelled agricultural machines are to an increasing extent equipped with electric motors, the energy supply to which is wholly or partly provided by power stores (e.g., batteries). Such machines can be designed as agricultural tractors or as self-propelled harvesting machines. The electric drive train may have a higher efficiency than a hydraulic drive train. For example, a generator driven by a main drive train is able to feed a battery which, during load peaks, is used to supply the generator, then serving as a motor, with power (EP 1 563 724 A1), or it is possible for a battery to assist or solely supply an electric-motor drive of a driven element of a harvesting machine as necessary, in addition to a motor-driven generator (EP 2 253 196 A1).

[0004] In order to store electrical energy in sufficiently large quantities, correspondingly large power stores are needed. Analogously, the motors and generators have to be configured to be sufficiently large. The result of this is that air cooling is no longer sufficient to cool the power store and the motors and generators. Instead, forcible cooling systems are needed in order to provide the cooling of these relatively large components. Electric motors and generators can generally be cooled by oil, while electronic components, such as inverters and DC-DC converters, are cooled by water, to which an antifreeze is usually added.

[0005] There remains the problem of cooling the power store. To this end, liquid-cooled arrangements have been described, see WO 2017/067923 A1. However, the working temperatures of conventional power stores, which are generally intended to lie below 40° C., are more likely not to be reached in conventional cooling systems when implemented in agricultural machines.

SUMMARY

[0006] A drive system for a self-propelled agricultural machine is provided. The drive system includes a power store, a DC-DC converter connecting the power store to a DC bus. An electric motor is connected to the DC bus via an inverter. A first cooling circuit is provided for dissipating heat from the power store. A cooling liquid circulates through the first cooling circuit. A second cooling circuit is provided for dissipating heat from the cooling liquid of the first cooling circuit. A refrigerant circulates through the second cooling circuit. A third cooling circuit is provided for dissipating heat from the refrigerant of the second cooling circuit, the DC-DC converter, and the inverter.

[0007] In other words, it is proposed to cool the DC-DC converter and the inverter by means of a third cooling circuit, which also cools a second cooling circuit which in turn cools a first cooling circuit of the power store. This three-stage cooling of the first cooling circuit has the advantage that a dissipation of heat from the power store is possible with little additional outlay, namely for the first and second cooling circuit. By means of the second cooling circuit, with a usable efficiency, a sufficiently high temperature gradient between the third and first cooling circuit can be achieved which, firstly, ensures usable temperatures for the power store and, secondly, permits the use for agricultural machines of conventional cooling circuits for electronic components.

[0008] The above features and advantages and other features and advantages of the present teachings are readily apparent from the following detailed description of the best modes for carrying out the teachings when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a schematic side view of a self-propelled forage harvester.

[0010] FIG. **2** is a schematic top view of a drive system of the forage harvester.

[0011] FIG. **3** is a schematic illustration of a cooling of electric motors and motor/generators for the drive of feed rollers of a harvesting attachment of the forage harvester.

[0012] FIG. **4** is a schematic illustration of the cooling of a battery.

DETAILED DESCRIPTION

[0013] Those having ordinary skill in the art will recognize that terms such as "above," "below," "upward," "downward," "top," "bottom," etc., are used descriptively for the figures, and do not represent limitations on the scope of the disclosure, as defined by the appended claims. Furthermore, the teachings may be described herein in terms of functional and/or logical block components and/or various processing steps. It should be realized that such block components may be comprised of any number of hardware, software, and/or firmware components configured to perform the specified functions.

[0014] The terms "forward", "rearward", "left", and "right", when used in connection with a moveable implement and/or components thereof are usually determined with reference to the direction of travel during operation, but should not be construed as limiting. The terms "longitudinal" and "transverse" are usually determined with reference to the fore-and-aft direction of the implement relative to the direction of travel during operation, and should also not be construed as limiting.

[0015] Terms of degree, such as "generally", "substantially" or "approximately" are understood by those of ordinary skill to refer to reasonable ranges outside of a given value or orientation, for example, general tolerances or positional relationships associated with manufacturing, assembly, and use of the described embodiments.

[0016] As used herein, "e.g." is utilized to non-exhaustively list examples, and carries the same meaning as alternative illustrative phrases such as "including," "including, but not limited to," and "including without limitation." As used herein, unless otherwise limited or modified, lists with elements that are separated by conjunctive terms (e.g., "and") and that are also preceded by the phrase "one or more of," "at least one of," "at least," or a like phrase, indicate configurations or arrangements that potentially include individual elements of the list, or any combination thereof. For example, "at least one of A, B, and C" and "one or more of A, B, and C" each indicate the possibility of only A, only B, only C, or any combination of two or more of A, B, and C (A and B; A and C; B and C; or A, B, and C). As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. Further, "comprises," "includes," and like phrases are intended to specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof.

[0017] Referring to the Figures, wherein like numerals indicate like parts throughout the several views, a self-propelled forage harvester is generally indicated at **10** in FIG. **1**. Referring to FIG. **1**, the forage harvester **10** is built on a framework **12** which is supported by driven front wheels **14** and steerable rear wheels **16**. The forage harvester **10** is operated from a driver's cab **18**, from which a harvesting attachment **20** in the form of a windrow picker is visible. Crop, for example grass or the like, picked up from the ground by means of the harvesting attachment **20**, is fed via a feed conveyor having feed rollers **22**, which are arranged within a feed housing **24** on the front side of the forage harvester **10**, to a chopper drum **26**, which is arranged below the driver's cab **18**, chops it into small pieces and discharges it to a post-processing device having two grain processor rolls **38** (which can be moved when harvesting grass or moved into a position at a distance) and a conveying device **28** following downstream. The material leaves the forage harvester **10** to a transport vehicle traveling alongside, via a discharge elbow **30** that is rotatable by actuators about an approximately vertical axis, is adjustable in inclination and has a discharge flap that is adjustable using actuators. In the following text, direction indications, such as sideways, downwards and upwards, relate to the forward movement direction V of the forage harvester **10**, which runs to the right in FIG. **1**.

[0018] FIG. **2** shows a top view of the drive arrangement of the forage harvester **10**. In the rear region of the forage harvester **10** there is an internal combustion engine **36**, in particular in the form of a diesel engine. The crankshaft **40** of the internal combustion engine **36** extends in the forward direction of the forage harvester **10**. During operation, the crankshaft **40** of the internal combustion engine **36** drives a longitudinal shaft **44**, which is connected to the first bevel gear **48** of a bevel drive mechanism **52**. The longitudinal shaft **44** also drives, via gear wheels **70**, **72** and a second longitudinal shaft **76**, a pumping unit **74**, which comprises a hydraulic pump for driving hydraulic motors for the forward drive of the harvesting machine, a steering pump, a pump **148** (see also FIG. **3**) for supplying the actuators for adjusting the discharge elbow, and a hydraulic pump for the oil supply of the control device of the hydrostatic drive for the forward drive of the harvesting machine **10**. It would also be conceivable, via one of the gearwheels **70**, **72** or a gearwheel (not shown) arranged between them, to drive further permanently driven elements, such as an electric generator for supplying the on-board power supply of the forage harvester **10**, and/or a blower drive for the supply of cooling air for the internal combustion engine **36**. The longitudinal shaft **76** additionally is in drive connection to a first motor/generator **124**. This can be a conventional three-phase motor with internal permanent magnets. The first motor/generator **124** is electrically connected to a first inverter **126** which, in turn, is connected to a DC bus **128**.

[0019] The second bevel gear **50** of the bevel drive mechanism **52** is connected to a transverse shaft **80**, which extends through a hollow shaft **106** connected to the belt pulley **82** to the side of the belt pulley **82** that faces away from the bevel drive mechanism **52** and, there, is connected to a clutch **78**. On the output side, the clutch **78** is connected to the hollow shaft **106**, which additionally drives a second motor/generator **102** on the side of the belt pulley **82** that faces the bevel drive mechanism **52** via gearwheels **96**, **108** and **100**. The clutch **78** enables the drive belt **84** and, with the latter, the chopper drum **26** and the conveying device **28** to be switched on and off. The clutch is disengaged and separated by means of an actuator **122**. The second motor/generator **102** is designed as a three-phase generator, analogous to the first motor/generator **124**, and is connected to a second inverter **130**. The inverter **130** is in turn connected to the DC bus **128**.

[0020] Furthermore, the DC bus **128** is connected to further inverters **132**, **134**, of which the inverter **134** is connected to a first electric motor **112**, which drives the feed rollers **22** of the feed conveyor via a gear mechanism **114**, and the inverter **136** is connected to a second electric motor **116** (arranged on board the forage harvester **10** or on the harvesting attachment **20**), which drives some, several or all the driven elements of the harvesting attachment **20**. In the case of the windrow picker shown in FIG. **1** as a harvesting attachment **20**, the electric motor **116** can, for example, drive the tined roller **134**, while the transverse screw conveyor **138** can be coupled in terms of drive to the feed rolls **22** of the feed conveyor or is driven by a further electric motor (not shown).

[0021] An electronic control device **94** has a signal-transmitting connection to an operator interface **98**, the inverters **126**, **130**, **132**, **134** and an actuator **122** of the clutch and an engine control device **42** of the internal combustion engine **36**. The DC bus **128** is connected via a DC-DC converter **146**, which can be isolated at the input or output side from the DC bus **128** by a relay, to a rechargeable power store **140** (also designated as a battery or accumulator), which additionally can be connected to an external charging station by means of a charging device **142** and a charging socket.

[0022] The function of the control device **94** and of the inverters **126**, **130**, **132**, **134** is such that the control device **94** instructs the bidirectional inverters **126** and **130** to operate the first and second motor/generator **124**, **102** as an electric motor or generator, and defines the respective torque and/or the rotational speed on the shaft of the motor/generator **124**, **102** and the phase angle of the power drawn or output. In an analogous way, the control device **94** commands the likewise bidirectional inverters **132**, **134** to operate the electric motors **112**, **116** as an electric motor or generator and defines the respective torque and/or the rotational speed on the shaft of the electric motor **112**, **116** and the phase angle of the power drawn or output. In other words, the motors/generators **124**, **102** can be switched as generator by the control device **94** in order to charge the power store **140** and to supply the electric motors **112**, **116** or to brake the chopper drum **26**, or they can be switched as motor in order to drive the chopper drum **26** (for grinding) or to accelerate (when starting up) or to use the internal combustion engine **36** as a brake in order to brake the chopper drum **26**. In an analogous way, depending on the instructions from the control device **94**, the electric motors **112**, **116** can drive the feed rollers **22** and the drivable elements of the harvesting attachment **20** in electric-motor operation and brake same in generator operation. The power flows each run via the DC bus **128**.

[0023] The drive arrangement illustrated in FIGS. **1** and **2** is accordingly configured to operate at least in the following operating modes under control by the control device **94**:

[0024] (a) Running up the rotational speed of the chopper drum **26**. In order to begin a harvesting operation, first of all the internal combustion engine **36** must be started, which can be initiated by an operator at their workplace in the cab **18** by means of an ignition key or in another way (e.g. via the operator interface **98**). The clutch **78** is initially still disengaged, i.e. the chopper drum **26** is at a standstill. The operator can initiate the harvesting operation via the operator interface **98**. In order to protect the clutch **78**, the control device **94** causes the inverters **126** to operate the first motor/generator **124** as a generator in order to supply the DC bus **128** with electrical power. At the same time, the control device **94** commands the inverter **130** to operate the second motor/generator **102** as an electric motor, so that it accelerates the chopper drum **26**. When approximately the same rotational speeds are present on the input and output of the clutch **78** (the control device **94** is connected to appropriate sensors for rotational speed detection in the first section of the drive train of the chopper drum **26**, located upstream of the clutch **78**, and in the second section of the drive train of the chopper drum **26**, located downstream of the clutch **78**, or can derive these rotational speeds from signals which are provided by the motor/generators **124**, **102** directly or by the inverters **126**, **130** by using the currents flowing through the motor/generator **124**, **102**), the clutch **78** is engaged and the second motor/generator **102** can be commanded to stop accelerating the second section of the drive train of the chopper drum **26**. By means of this procedure, the clutch **78** is relatively lightly loaded and has a longer lifetime than if it were to be engaged when the chopper drum **26** was at a standstill.

[0025] (b) Harvesting operation. In normal harvesting operation, the internal combustion engine **36** drives the chopper drum **26** and the conveying device **28** via both sections of the drive train which are connected by the clutch **78**. The first motor/generator **124** is used as a generator and supplies electrical energy to the DC bus **128**, which in turn is used to supply the electric motors **112**, **116** which drive the feed rollers **22** and drivable elements of the harvesting attachment **20**. The electric motors **112**, **116** are activated in response to a corresponding operator entry by means of the operator interface **98**. The second motor/generator **102** can likewise be operated as a generator in harvesting operation and supply the DC bus **128**, or it runs freely without any power discharge or consumption. Furthermore, depending on demand, in this regard see the explanations further below, the power store **140** can supply additional energy, be it for the electric motors **112**, **116** or in special cases with high loading of the chopper drum **26** and/or the conveying device **28**, for the first and/or second motor/generator **124**, **102**. It is advisable to use the first motor/generator **124** preferably as compared with the second motor/generator **102** for converting the mechanical energy provided by the internal combustion engine **36** into electrical energy, since here the clutch **78** is not loaded, while the second motor/generator **102** is used for operating conditions under which the chopper drum **26** and/or the conveying device **28** have to have mechanical energy applied.

[0026] The rotational speed of the electric motor **112**, together with the rotational speed of the chopper drum **26**, determines the cutting length of the crop. This can be predefined by the operator by means of the operator interface **98** or sensors detect crop properties and define the cutting length and thus the rotational speed of the electric motor **112** which is controlled by the control device **94** and the inverter **132**. The rotational speed of the electric motor **116** can be fixedly predefined or depend on the cutting length and/or the forward drive speed of the forage harvester **10**, cf. EP 1 609 351 A1.

[0027] (c) After the harvesting operation or in the case of interruptions, it is expedient to stop the chopper drum **26**, firstly to avoid the risk of accidents, secondly to reduce noise. For this purpose, in response to an appropriate entry of the operator into the operator interface **98** or otherwise sensor-based detection of a non-harvesting situation, e.g. when the operator leaves their seat, after the clutch **78** has been disengaged, the second motor/generator **102** is operated as a generator and converts the rotational energy of the chopper drum **26** and of the conveying device **28** into electrical energy, which is supplied to the power store **104** via the DC bus **128** and, in particular, if the latter is sufficiently charged, is supplied to the first motor/generator **124**, which is operated as a motor and drives the internal combustion engine **36** actively, so that as a result of this compression action of the cylinders and pistons and friction, engine braking is carried out in order to convert the rotational energy of the chopper drum **26** into heat.

[0028] (d) Furthermore, the second motor/generator **102** can be used with the clutch **78** disengaged to drive the chopper drum **26** for grinding with a rotational speed and/or direction of rotation that is changed relative to the harvesting operation. The second motor/generator **102** is then operated as a motor and, if the internal combustion engine **36** is at a standstill, is supplied from the power store or, if the internal combustion engine **36** is running, has electrical power applied to it from the first motor/generator **124**. In this regard, reference is made to DE 10 2018 211 863 A1, the disclosure of which is included by reference in full in the present documents.

[0029] (e) The forage harvester **10** is further equipped with a foreign body detector **144**, which can be designed as a metal detector and/or as a stone detector for the detection of impinging stones and can be installed in the front, upper feed roller **22**. When the foreign body detector **144** responds, the control device **94** connected thereto receives a corresponding signal and causes the electric motor **112** to stop. The latter then operates as a generator and the power produced is transmitted via the DC bus **128** to the first motor/generator **124**, which converts it by means of the internal combustion engine **36** into heat, analogous to operating mode (c). The engine **116** is also stopped in the manner described.

[0030] (f) Hitherto, substantially a so-called hybrid electrical operation has been described, in which in harvesting operation the internal combustion engine **36** drives the motor/generator **124**, **102**, which in turn supplies the electric motors **112** and **116** with power. Here, the power store **140** is in principle not needed and could also be omitted. By comparison, however, the power store **140** has the advantage that at least a temporary increase in the total drive output of the forage harvester **10** is possible. Therefore, so-called battery operation of the forage harvester **10** is in particular also provided.

[0031] For the battery operation, firstly the hybrid electric operation is switched on. The power store **140** can be added via an entry on the operator interface **98**. For this purpose, the voltage state of the power store **140** is read by the control device **94**. A voltage equal to the current voltage of the power store **140** is predefined to the inverter **126** of the first motor/generator **124** in order to achieve the state in which a minimum current flows to the DC bus **128** at the instant at which the power store **140** is connected. Once this state has been reached, the relay connected to the DC-DC converter **146** of the power store **140** is switched on. The feed rollers **22** and the elements of the harvesting attachment **20** driven by the electric motor **116** can then be fed directly and exclusively (or at least partly, depending on the respective power demand) from the power store **140**. This power, previously applied by the internal combustion engine **36**, is then free there and can be used for other purposes, specifically in particular for the drive of the chopper drum **26**.

[0032] In battery operation, the first motor/generator **124** is active as a generator but in harvesting operation provides no power for the electric motors **116**, **118** (depending on the throughput and power demand). This is then taken exclusively or partly from the battery. If only relatively little power is needed by the forage harvester, for example in the headland or during a transport journey, a higher voltage than from the power store **140** is provided to the first motor/generator **124** by the control device **94**, so that a current flows into the power store and the latter can be recharged. In principle, recharging is carried out when idling, in the headland and during transport.

[0033] In addition, even during harvesting operation, under small loads the power store **140** can be charged by the first motor/generator **124** by raising its target voltage. This can primarily be used to displace the load points of the internal combustion engine **36** to a higher efficiency in the fuel consumption characteristic map. Thus the overall efficiency of the forage harvester **10** is raised and less CO_2 is discharged.

[0034] By means of the electrical drive of the harvesting attachment by the electric motor **116**, the electrical power taken by the latter, which is a measure of the throughput, can be measured permanently. If the stand in parts of the field is particularly dense, an increased power demand can be detected on the harvesting attachment **20**. In order to be able to maintain the speed of travel without provoking blockage of the forage harvester **10**, a rotational speed predefinition can be sent to the inverter **126** of the first motor/generator **124** with the effect that the internal combustion engine **36** is boosted with energy from the power store **140** by means of additional torque from the first motor/generator **124**, and thus does not fail. As already described above, additionally or alternatively the second motor/generator **102** upstream of the clutch **78** can also be used in order to maintain the rotational speed of the chopper drum **26**.

[0035] It should also be noted that a series of modifications of the embodiments illustrated are conceivable. Thus, the drives of the wheels **14**, **16** could also be performed by electric motors, which are each connected to the DC bus **128** by inverters and are controlled by the control device **94**, instead of by hydrostatic drives. Here, an electric motor can drive both wheels **14** or **16** of the front and/or rear axle jointly via a gearbox or the wheels are driven individually, in particular by wheel-hub motors. Analogously, the drive of the fan of the main cooling assembly can be electrified. For this purpose, both a single, central electric motor for driving the fan of all the coolers and also a fan array having a plurality of motors and fans are conceivable, which ventilates the individual coolers under application and temperature control.

[0036] Furthermore, the drive of the grain processor rollers **38** could be carried out by one or two electric motors, which are connected to the DC bus **128** in a way analogous to the electric motors **112**, **116**. Here, reference is also made to DE 10 2021 113 626 A1, DE 10 2018 205 221 A1 and DE 10 2013 110 636 A1, the disclosures of which are included by reference in full in the present documents.

[0037] Finally, it should also be noted that the operating mode (e) does not depend on the second motor/generator **102** being present, but could also be applied in a forage harvester **10** without this second motor/generator **102**. This applies analogously to stopping the feed rollers **22** and the driven elements of the harvesting attachment **20** when the foreign body detector **144** responds in the operating mode (e) described. The details discussed hitherto are also found in DE 10 2023 135 106 A1, the disclosure of which is included by reference in the present documents.

[0038] FIG. **3** illustrates how the cooling of the electric motors **112**, **116** and the motors/generators **102**, **124** is carried out. Hydraulic fluid is taken from a hydraulic oil tank **148** by means of a pump **150**, which can be a constituent part of the pumping unit **74**, and supplied to a valve block **150**. The latter contains an outlet **152** connected directly to its inlet **154** and to which further hydraulically operated elements can be connected, such as actuators for adjusting the discharge elbow **30** or for driving a rotating cleaning screen for cooling air.

[0039] The valve block **150** also comprises a number of throttle valves **156** to **170**, which on the inlet side are each connected to the inlet **154** and on the outlet side are connected to one of the electric motors **112**, **116** or the motors/generators **102**, **124**. Accordingly, each of the electric motors **112**, **116** and motors/generators **102**, **124** receives two flows of hydraulic fluid through associated lines **172** and **174**. In each case one of these lines **172** leads the hydraulic fluid to the stator and another of the lines **174** leads it to the rotor of the electric motor **112**, **116** or motor/generator **102**, **124**.

[0040] The electric motors **112**, **116** and motors/generators **102**, **124** also each comprise an outlet, which is connected to a return tank **178** via a respective line **176**. From there, the hydraulic fluid flows, preferably unpressurized, back into the hydraulic oil tank **148**. The latter is additionally connected to an oil cooler **180**, which is cooled by an air stream in order to reduce the temperature of the hydraulic fluid.

[0041] The power store **140** is also equipped with cooling, which is illustrated schematically in FIG. **4**. The power store **140** can be subdivided into two or more units which, for example, has the advantage of modular extendibility and exchangeability, as shown in FIG. **4**. Because of the high output when charging and discharging the one or more power stores **140**, a certain amount of heat loss is produced, which must be dissipated. In addition, at low temperatures, warming up the power stores **140** may also be expedient. The power stores **140** therefore have their temperature controlled via a dielectric (non-conducting) cooling liquid, which flows around the individual cells of the power stores **140**, see WO 2017/067923 A1.

[0042] This dielectric cooling liquid circulates in a first circuit **182**. An expansion tank **184** can accommodate a certain quantity of the dielectric cooling liquid. A first cooling liquid pump **186** conveys the dielectric cooling liquid through a line **188** to an adjustable bypass valve **190**, from which part of the dielectric cooling liquid is guided directly and part via a first heat exchanger **192** to a filter **194**. On the outlet side, the filter **194** is connected to an inlet of the power stores **140**, while the outlet of the power stores is in turn coupled to the expansion tank **184** and the inlet of the first cooling liquid pump **186**. In this way, the first cooling liquid pump **186** effects a circulation of the dielectric cooling liquid around the cells of the power stores **140**, wherein the proportion of the dielectric cooling liquid which is guided through the first heat exchanger **192** can be varied by the adjustable bypass valve **190**.

[0043] The aforesaid dissipation of heat from the dielectric cooling liquid is carried out by the first heat exchanger **192**, which is cooled by a second circuit **198**. In addition to the first heat exchanger **192**, this comprises a compressor **200** and a second heat exchanger **202**, in particular embodied as a plate heat exchanger, and an expansion valve **204**. The second circuit **198** accordingly operates as a heat pump, in that the compressor **200** compresses the refrigerant heated in the first heat exchanger **192** and circulating in the second circuit **198** (e.g. a refrigerant that is usual for heat pumps or air-conditioning systems) and no longer heats the refrigerant, so that the heated refrigerant gives up its heat to a third cooling circuit **206** in the second heat exchanger **202**. The pressure of the refrigerant, which is now cooler, is reduced again in the expansion valve **204**.

[0044] The third cooling circuit **206** comprises a second cooling liquid pump **210**, which is connected on the inlet side to the outlet of a cooler **208** through which air flows. The airflow through the cooler **208** is produced by means of a blower **218**. The inlet of the second cooling liquid pump **210** is also connected to an expansion tank **212**. On the outlet side, the second cooling liquid pump **210** is connected to a bypass valve **216**. Its first outlet is connected to the second heat exchanger **202** by lines, and to the inverters **126**, **130**, **132**, **134** (or channels on or in heat sinks of the inverters in order to cool their electronic components, cf. for example WO 2016/094059 A1). On the outlet side, these are connected to the inlet of the cooler **208** by lines. The second outlet of the bypass valve **216** is connected to the charging device **142**, connected in series in the embodiment illustrated for the cooling liquid, and to the DC-DC converter **146**, the outlet of which is in turn connected to the cooler **208**. The third cooling circuit **206** can use water to which antifreeze (e.g. glycol), for example, is added as a cooling liquid. This cooling liquid is supplied by the second cooling liquid pump **210** as required, via the bypass valve **216**, to the charging device **142** and the DC-DC converter **146** and also the inverters **126**, **130**, **132**, **134** and the cooler **208**.

[0045] The electronically adjustable rotational speeds of the cooling liquid pumps **186** and **210** and also of the compressor **200** can be controlled by the control device **94** on the basis of sensors for detecting the temperatures of the cooling liquids and refrigerants in the three cooling circuits **182**, **198**, **206** (or on the basis of the temperatures of the components to be cooled). In an analogous way, the bypass valves **190** and **216** can also be controlled by the control device **94**.

[0046] The detailed description and the drawings or figures are supportive and descriptive of the disclosure, but the scope of the disclosure is defined solely by the claims. While some of the best modes and other embodiments for carrying out the claimed teachings have been described in detail, various alternative designs and embodiments exist for practicing the disclosure defined in the appended claims.

What is claimed is:

1. A drive system for a self-propelled agricultural machine, the drive system comprising:
- a power store;
- a DC bus;
- a DC-DC converter connecting the power store and the DC bus;
- an inverter;
- an electric motor connected to the DC bus via the inverter;
- a first cooling circuit operable to circulate a cooling liquid therethrough for dissipating heat from the power store;
- a second cooling circuit operable to circulate a refrigerant therethrough for dissipating heat from the cooling liquid of the first cooling circuit; and
- a third cooling circuit configured for dissipating heat from the refrigerant of the second cooling circuit, the DC-DC converter, and the inverter.

2. The drive system set forth in claim **1**, further comprising an internal combustion engine and a motor/generator that can be brought into drive connection with the internal combustion engine and which is connected by means of a second DC-DC converter to the DC bus, wherein the third coolant circuit is configured for dissipating heat from the second DC-DC converter of the motor/generator.

3. The drive system set forth in claim **1**, wherein the second cooling circuit includes a heat pump.

4. The drive system set forth in claim **1**, further comprising a cooler operable to dissipate heat from the third cooling circuit into surrounding air.

5. The drive system set forth in claim **4**, further comprising a blower operable to generate an air stream that is applied to the cooler.

6. The drive system set forth in claim **1**, wherein the first cooling circuit and the second cooling circuit are thermally connected by a first heat exchanger.

7. The drive system set forth in claim **6**, wherein the second cooling circuit and the third cooling circuit are thermally connected by a second heat exchanger.

8. The drive system set forth in claim **7**, wherein the second cooling circuit includes a compressor disposed between the first heat exchanger and the second heat exchanger, and an expansion valve between the second heat exchanger and the first heat exchanger.

9. The drive system set forth in claim **2**, wherein the electric motor and the motor/generator are each cooled by a hydraulic fluid.

10. An agricultural harvesting machine comprising:
a power store;
a DC bus;
a first DC-DC converter connecting the power store and the DC bus;
an inverter;
an electric motor connected to the DC bus via the inverter;
an internal combustion engine;
a motor/generator that can be brought into drive connection with the internal combustion engine and which is connected by means of a second DC-DC converter to the DC bus;
a first cooling circuit operable to circulate a cooling liquid therethrough for dissipating heat from the power store;
a second cooling circuit operable to circulate a refrigerant therethrough for dissipating heat from the cooling liquid of the first cooling circuit;
a third cooling circuit configured for dissipating heat from the refrigerant of the second cooling circuit, the first DC-DC converter, the inverter, and the second DC-DC converter of the motor/generator.

11. The agricultural harvesting machine set forth in claim **10**, wherein the second cooling circuit includes a heat pump.

12. The agricultural harvesting machine set forth in claim **10**, further comprising a cooler operable to dissipate heat from the third cooling circuit into surrounding air.

13. The agricultural harvesting machine set forth in claim **12**, further comprising a blower operable to generate an air stream that is applied to the cooler.

14. The agricultural harvesting machine set forth in claim **10**, wherein the first cooling circuit and the second cooling circuit are thermally connected by a first heat exchanger.

15. The agricultural harvesting machine set forth in claim **14**, wherein the second cooling circuit and the third cooling circuit are thermally connected by a second heat exchanger.

16. The agricultural harvesting machine set forth in claim **15**, wherein the second cooling circuit includes a compressor disposed between the first heat exchanger and the second heat exchanger, and an expansion valve between the second heat exchanger and the first heat exchanger.

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