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SVEUČILIŠTE U ZAGREBU

FAKULTET ŠUMARSTVA I DRVNE TEHNOLOGIJE

Svetošimunska cesta 25

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Zagreb, 05. srpnja 2022.

Predmet: Studija provjere i zaštite intelektualnog vlasništva – Razvoj hibridnog skidera - HiSkid

Tehničko rješenje koje je bilo predmet provjere je hibridni šumski traktor kojem je uz dizelski motor pridružen elektromotor odvojen sa dvije spojke s čime se omogućuju više režimski modovi rada i zamjena pogona vitla temeljenog na hidrauličkom pogonu sa pogonom zasnovanim na elektromotoru.

Provjera tehničkog rješenja u smislu zaštite intelektualnim vlasništvom, na temelju opisa i popratnih crteža, izvršena je pretraživanjem patentnih baza podataka, baza podataka industrijskih dizajna i internetske tražilica Google radi pronalaženja informacija pohranjenih na drugim mrežnim mjestima.

Cilj pretraživanja je pronaći slična rješenja tehničkog problema te izvršiti usporedbu predmetnog rješenja s pronađenim pri čemu se traže razlike koje moraju zadovoljiti uvjete zaštite /novost i/ili inventivni korak/. Na temelju procjene novosti i inventivnog koraka predlaže se oblik zaštite industrijskog vlasništva i izrađuje se prijavna dokumentacija za pokretanje postupka zaštite.

«Pod stanjem tehnike razumijeva se sve što je učinjeno pristupačnim javnosti u svijetu, pisanim ili usmenim putem, uporabom ili na bilo koji drugi način prije datuma podnošenja prijave patenta.» /članak 8. stavak 2. ZOP-a/:

Novost i inventivna razina različiti su kriteriji.
Novost postoji ako postoji bilo kakva razlika između izuma i poznatog stanja tehnike.
Inventivna razina je razlika koja za stručnu osobu iz odgovarajućeg područja ne proizlazi na očigledan način iz stanja tehnike.
Procjenjivanje inventivne razine sastoji se u provjeravanju da li, s obzirom na «najbliže prethodno stanje tehnike», izum «ne bi bio očigledan» stručnjaku u određenom području. To je jedan od temelja svakog sustava zaštite izuma.

Sve stručne informacije temeljene su na dostupnim patentnim dokumentima koji su objavljeni u R. Hrvatskoj, Europskoj uniji, Sjedinjenim Američkim Državama te u bazi svjetske organizacije /WIPO/.

Konzultirane baze podataka su slijedeće:
- Espacenet - https://worldwide.espacenet.com/ - 130 milijuna patentnih dokumenata;
- Patentscope - https://patentscope.wipo.int/ - 105 milijuna patentnih dokumenata uključujući 4,4 milijuna objavljenih međunarodnih patentnih dokumenata (PCT);
- US patentni ured - https://appft.uspto.gov/netahtml/PTO/;
- Državni zavod za intelektualno vlasništvo - https://www.dziv.hr/hr/e-usluge/e-registri/patent/

Osim spomenutih baza, pretraživale su se i informacije pohranjene na drugim mrežnim mjestima putem internetske tražilice Google. Informacije koje se nalaze na web stranicama, slike, prezentacije i ostale vrste datoteka.
Adresa: http://www.google.com

S obzirom na veliki broj patentnih dokumenata, njihovu složenost i dostupnost, pretraživanje zahtijeva određena znanja u korištenju patentnih baza podataka te znanje iz različitih područja tehnike. Kako bi pretraživanje bilo uspješno potrebno je odrediti vrstu pretraživanja, dobro definirati parametre pretraživanja te vršiti vremensko praćenje za cijelo vrijeme razvoja inovativnog koncepta (novog proizvoda/postupka) odnosno do trenutka podnošenja zahtjeva za zaštitom. Što se ranije, još u fazi razvoja projekta, detektira tuđe rješenje, patent ili patentna prijava, lakše će biti izbjeći povredu prava, a ujedno se otvara mogućnost o razmatranju smjera daljnjeg istraživanja i razvoja.

Pretraživanjem baza patentnih dokumenata dolazi se do informacija, tehničke i pravne naravi, koje:

- ukazuju na zaštićena rješenja /proizvode i postupke/ te na taj način se izbjegava povreda tuđih prava,
- definiraju stanje tehnike /poznata rješenja određenog tehničkog problema/ u određenom području,
- se mogu koristiti pri donošenju odluka o ulaganju u istraživačke i razvojne projekte tj. u razvoj novog proizvoda ili postupka,
- otvaraju nove poglede i ideje koje mogu dovesti do novih rješenja ili usavršavanja postojećih,
- ukazuju na smjer i interes razvoja konkurencije /pogled u budućnost/,
- otkrivaju tehnička rješenja zanimljiva za otkup prava ili licenciranje,
- otkrivaju slobodne proizvode i tehnologije /istekla patentna prava ili rješenja koja nisu zaštićena u određenim državama/,
- otkrivaju slobodna tržišta /rješenja koja nisu zaštićena u određenim državama/,
- pomažu pri izradi patentne prijave i sastavljanju patentnih zahtjeva.

Strategija pretraživanja:

- pretraživanje za točno određeno tehničko rješenje ili barem dobro razrađenu ideju na temelju ključnih riječi ili pojmova. Pronađeni dokumenti daju pregled najnovijih tehničkih dostignuća/inovacija u određenom tehničkom području;
- pretraživanje prema bibliografskim podacima (naziv podnositelja, naziv nositelja, naziv izumitelja, broj prijave ili registracije, relevantni datumi, te ostali podaci). Praćenje konkurencije, potencijalnih poslovnih partnera i sl.;
- pretraživanje da li je istovjetni inozemni dokument registriran u R. Hrvatskoj ili nekoj drugoj državi. Pokazuje „zauzetost“ tržišta.;
- pretraživanje o pravnom statusu patentnog dokumenta. Omogućuje spoznaju u kojoj se fazi postupka priznanja ili održavanja u vrijednosti navedeni dokument nalazi i u kojoj određenoj zemlji;
- redovito pretraživanje određenog tehničkog područja /klasifikacijske oznake/ na temelju istovjetnog upita u određenim vremenskim intervalima – prati se razvoj tehnologije;
- redovito pretraživanje u određenom tehničkom području /klasifikacijska oznaka/ na temelju naziva podnositelja u određenim vremenskim intervalima – prate se aktivnosti /smjer razvoja/ konkurencije;

- pretraživanje radi procjene sličnosti ili istovjetnosti jednog proizvoda/postupka s drugim kako bi se izbjegla povreda tuđih prava.

Relevantni patentni dokumenti izdvojeni iz rezultata pretraživanja su:
- patentna prijava broj US4662472A,
- međunarodne patentne prijave WO2010130284A,
- međunarodne patentne prijave WO2010136072A,
- međunarodne patentne prijave WO2020165819A.

Stanje zaštite:
- US4662472A – ugašeno zbog neodržavanja;
- WO2010130284A – na temelju međunarodne prijave nastavljen je nacionalni i regionalni postupak - američki patent US8649927B – istekao zbog neodržavanja; „europski" patent EP2429871 - u R. Hrvatskoj nije bio registriran /nije dostavljen prijevod i nisu plaćene pristojbe/, u ostalim zemljama EU patent je ugašen;
- WO2010136072A - odustalo se od patentnog postupka;
- WO2020165819A – na temelju međunarodne prijave nije se išlo dalje u nacionalne i/ili regionalne faze – patent priznat u Indiji pod brojem 344807.

Svi navedeni dokumenti su važni samo za stanje tehnike.
Ne postoji opasnost od povrede patentnih prava.

Kratki opis s komentarom rješenja koja su objavljena u patentnim dokumentima:

1. Rješenje pod nazivom „Električni traktor", patentna prijava broj US4662472A, prijavitelji: Christianson Leslie L; Alcock Ralph; Froehlich Donell P; Hellickson Mylo A, prikazuje zglobni električni traktor na baterijski pogon koji uključuje prednje i stražnje elemente okvira zakretno povezane. Kotači podupiru elemente okvira za vožnju po tlu. Električna energija je pohranjena u baterijama koje su postavljene na stražnji dio okvira. Prvi elektromotor montiran je na stražnji element okvira i koristi se za pogon kotača traktora. Drugi elektromotor je montiran na prednji element okvira i koristi se za pogon priključnog vratila. Električni traktor prema izumu koristi dva neovisno upravljana elektromotora. Korištenjem dva odvojena motora, svakim pojedinačno kontroliranim, moguće je neovisno mijenjati brzinu vozila i brzinu priključnog vratila.

Električni traktor napaja se industrijskim olovnim baterijama. Baterije su sposobne napajati traktor četiri do osam sati. Trenutno stanje napunjenosti baterija važna je informacija za operatera traktora stoga se u kabini nalaze instrumenti koji prikazuju informacije o trenutnom stanju baterija. Baterije zahtijevaju periodično održavanje.

2. Rješenje pod nazivom ENERGETSKI SUSTAV ZA HIBRIDNO VOZILO, broj objave međunarodne patentne prijave WO2010130284A, podnositelji prijave: EL FOREST AB [SE]; GUSTAVSSON ROGER [SE], prikazuje metodu i uređaj za upravljanje radom energetskog sustava za hibridno vozilo, pri čemu energetski sustav vozila sadrži: motor s unutarnjim izgaranjem koji se kontrolira da radi na željenoj brzini rotacije motora; električni generator/motor kojeg pokreće motor s unutarnjim izgaranjem; uređaj koji troši energiju postavljen tako da ga pokreće motor s unutarnjim izgaranjem i može pokretati električni generator/motor; i uređaj za pohranu energije povezan s električnim generatorom/motorom i postavljen za primanje proizvedene električne energije od strane električnog generatora/motora.

Cilj ovog izuma je osigurati energetski učinkovit rad hibridnog vozila koje sadrži uređaj koji troši značajnu energiju, kao što je hidraulički sustav za podizanje. Ovaj i drugi ciljevi se postižu metodom upravljanja radom energetskog sustava za hibridno vozilo, pri čemu metoda uključuje praćenje brzine vrtnje motora i kontroliranje električnog generatora/motora za proizvodnju električne energije. Bit rješenja je u izboru manjeg motora s unutarnjim izgaranjem /manja snaga, manja potrošnja goriva, manje zagađenje…/ na način da se u radnom opterećenju vozila, ovisno o potrebnoj energiji regulira njena proizvodnja tj. potrošnja. Kada je potrebna veća snaga/brzina rotacije ista se osigurava preko generator/motora koji će tada raditi kao elektromotor koji će se napajati iz baterije i obrnuto kada je potrebna manja snaga generator/motor će puniti bateriju a može i direktno pogoniti elektromotore kotača. Stvarnu brzinu vrtnje motora s unutarnjim izgaranjem nadzire kontroler koji prikuplja signale od jednog ili više senzora koji osjete brzinu rotacije radilice motora s unutarnjim izgaranjem, rotora električnog generatora/motora, hidrauličke pumpe ili vratila koja mehanički povezuju glavne dijelove energetskog sustava. Stvarna brzina vrtnje motora prati se i uspoređuje s unaprijed određenim brzinama vrtnje motora.

3. Rješenje pod nazivom Hibridno komunalno vozilo, broj objave međunarodne patentne prijave WO2010136072A, podnositelji prijave: EL FOREST AB [SE]; GUSTAVSSON ROGER [SE], u kojemu je prikazano hibridno komunalno vozilo kod kojeg karoserija vozila sadrži skup pogonskih kotača, gdje svaki set pogonskih kotača sadrži dva kotača postavljena na

suprotnim stranama vozila, gdje se kotači pokreću odgovarajućom pogonskom jedinicom, pri čemu se brzina rotacije svakog kotača može podesiti neovisno o brzini rotacije drugih kotača. Ovaj izum se može implementirati u zglobno vozilo. Hibridno komunalno vozilo /forvarder/ sastoji se od kabinskog dijela, ležaja za držanje posječenog drveta, te hidrauličkog alata za utovar/istovar posječene drvene građe. Hibridni forvarder je dodatno opremljen sa šest kotača, od kojih svaki pokreće pridruženi elektromotor kojim se pojedinačno može upravljati. Električni motori koji pokreću kotače i hidraulički alat za manipulaciju pokreću se pogonskim sustavom. Forvarder također sadrži aktuatore u obliku hidrauličnih cilindara dvostrukog djelovanja. Pogonski sustav se sastoji od motora s unutarnjim izgaranjem, električnog generator/motora, uređaja za pohranu energije, hidrauliče pumpe za napajanje alata za manipulaciju i hidrauličkih cilindara. Električni generator/motor električno je povezan s uređajem za pohranu energije, koji zauzvrat osigurava električnu energiju elektromotorima koji pokreću kotače i hidrauličku pumpu. Električni generator/motor također može opskrbljivati električnom energijom izravno elektromotore koji pokreću kotače. Za upravljanje radom pogonskog sustava, isti je opremljen upravljačkom jedinicom povezanom s električnim generatorom/motorom. Upravljačka jedinica kontrolira rad motora i hidrauličkih cilindara. Upravljanje hidrauličkim cilindrima se izvodi preko ventila kojima može upravljati upravljačka jedinica, a svaki je povezan s odgovarajućim hidrauličkim cilindrom. Upravljačka jedinica također je spojena na pokazivače položaja, tako da upravljačka jedinica može primati signale od njih i odrediti položaj vozila i upravljati motorima i hidrauličkim cilindri kao odgovor na to.

4. Rješenje pod nazivom Hibridno poljoprivredno vozilo, broj objave međunarodne patentne prijave WO2020165819A, podnositelj prijave: PROXECTO ENG SERVICES LLP [IN], u kojemu je prikazano hibridno vozilo koje se sastoji od: podnice; motora s unutarnjim izgaranjem montiranim na podnicu kojim upravlja elektronička upravljačka jedinica; alternator, mehanički spojen s motorom s unutarnjim izgaranjem; niz prednjih i stražnjih elektromotora kojima se upravlja pomoću više kontrolera za upravljanje zakretnim momentom; i niz prednjih i stražnjih kotača. Motor s unutarnjim izgaranjem, kojim upravlja elektronička upravljačka jedinica, pogoni alternator koji proizvodi električnu energiju za rad elektromotora koji pokreću kotače vozila i elektromotor za radni priključak /alat/. Elektromotori su u direktnom spoju s kotačima. Elektromotorima upravljaju kontroleri za upravljanje zakretnim momentom. Zahtjevi za opterećenje šalju se regulatorima upravljanja snagom koji kontroliraju alternator i proces proizvodnje energije. Elektronička upravljačka jedinica kontrolira količinu goriva koja ulazi u motor s unutarnjim izgaranjem u bilo kojem trenutku i zauzvrat dobiva upravljačke naredbe od

kontrolera upravljanja snagom. Motor s unutarnjim izgaranjem mehanički je spojen s alternatorom i cjelokupna izlazna snaga motora pretvara se u električnu energiju pomoću alternatora. Između alternatora i elektromotora nema uređaja za pohranu energije.

Zaključak:

Razlikovne karakteristike izuma u odnosu na stanje tehnike:

- uz klasični pogon skidera ukomponirana su dva elektromotora sa popratnim elementima i sklopovima, od kojih je jedan povezan s dizelskim motorom i u kombinaciji s njim proizvoditi potrebnu snagu za rad skidera, a drugi je povezan s vitlom kojeg i pogoni;
- više režimski modovi upravljanja drže radnu točku dizelskog motora u optimalnom području (području minimalne specifične potrošnje goriva);
- skiderom upravlja upravljačka jedinica kroz algoritam upravljanja koji analizira podatke sa motora i potrošnju goriva;
- pogon vitla elektromotorom, pri čemu drugi elektromotor, kojeg pogoni dizel motor, postaje generator koji puni bateriju.

Mogući oblici zaštite industrijskog vlasništva za predmetno rješenje jesu patent i/ili industrijski dizajn. S obzirom na razliku u opsegu zaštite predlaže se patent. Pokretanje patentnog postupka zaštite daje potencijalnim investitorima sigurnost da daljnje ulaganje u izradu prototipa ili u dodatno usavršavanje, smanjuje rizik u komercijalizaciji predmetnog rješenja i ostvaruje prednost u odnosu na konkurenciju na tržištu.

Dokumente relevantne za stanje tehnike /u digitalnom obliku/ dostavljamo u privitku.

S poštovanjem,

INOVA d.o.o.

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

[Continued on next page]

(54) **Title**: ENERGY SYSTEM FOR A HYBRID VEHICLE

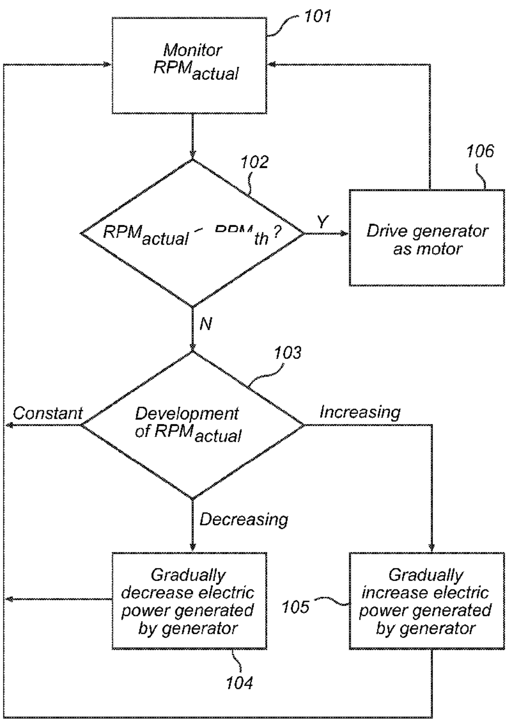

Fig. 3

(57) Abstract: A method of controlling operation of an energy system (10) for a hybrid vehicle (1), the energy system (10) comprising: a combustion engine (11) being controlled to work at a desired engine rotational speed ($RPM_{desired}$); an electric generator/motor (12) arranged to be driven by the combustion engine (11) to output a generated electric power; a power consuming device (14) arranged to be driven by the combustion engine (11) and drivable by the electric generator/motor (12); and an energy storage device (13) connected to the electric generator/motor (12) and arranged to receive the generated electric power output by the electric generator/motor (12). The method comprises the steps of: monitoring (101) an actual engine rotational speed (RPM_{actual}); and if the actual engine rotational speed (RPM_{actual}) decreases from the desired engine rotational speed ($RPM_{desired}$), controlling (104) the electric generator/motor (12) to output a gradually reducing generated electric power. Hereby, the combustion engine can be allowed to remain in an operating range where it works efficiently, while at the same time fulfilling the need for power of the power consuming device.

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ENERGY SYSTEM FOR A HYBRID VEHICLE

Technical Field of the Invention

The present invention relates to a method and device for controlling operation of an energy system for a hybrid vehicle, and to such a hybrid vehicle.

Technical Background

As a part of the ongoing effort to reduce the emission of greenhouse gases into the atmosphere, more energy-efficient vehicles are currently being developed.

One class of such vehicles are so-called hybrid vehicles, that are provided with an energy system with a combustion engine, an electric generator/motor and an energy storage device, such as batteries or capacitors. By intelligently using the energy stored in the energy storage device, the combustion engine can be run more efficiently, which leads to a reduction in the amount of CO_2 per kilometer that is emitted by the hybrid vehicle.

Hybrid vehicles in the form of cars are abundant on the market today. However, hybrid vehicles in the form of construction equipment and other utility vehicles provided with an additional substantial power consuming device, such as a hydraulic lifting system are scarcely found.

Summary of the Invention

In view of the above, a general object of the present invention is to provide for energy efficient operation of a hybrid vehicle comprising a substantial power consuming device, such as a hydraulic lifting system.

According to a first aspect of the present invention, these and other objects are achieved through a method of controlling operation of an energy system for a hybrid vehicle, the energy system comprising: a combustion engine being controlled to work at a desired engine rotational speed; an electric generator/motor arranged to be driven by the combustion engine to output a generated electric power; a power consuming device arranged to be driven by the combustion engine and drivable by the electric generator/motor; and an energy storage device connected to the electric generator/motor and arranged to receive the generated electric power output by the electric generator/motor, wherein the method comprises the steps of: monitoring an actual engine rotational speed; and if the actual engine rotational speed decreases from the desired engine rotational speed, controlling the electric generator/motor to output a gradually reducing generated electric power.

It should be noted that the method according to the present invention by no means is limited to performing the steps thereof in any particular order.

In the development of an energy system for a hybrid vehicle comprising a substantial power consuming device, new challenges have been encountered by the present inventor. For example, unpredictable demand of power from the power consuming device may lead to a total demand for more power than can be generated by the combustion engine, which may then stall.

An obvious solution to this problem would be to provide a larger combustion engine, but with such a solution the advantages of the hybrid vehicle, such as the increased energy-efficiency, are not fully realized. Furthermore, an over-dimensioned combustion engine adds to the cost of the hybrid vehicle.

In view of these new challenges faced by the present inventor, the present invention is based on the realization that energy efficient operation of a hybrid vehicle with a substantial power consuming device can be achieved by monitoring the actual engine rotational speed, and, if the actual engine rotational speed decreases from the desired engine rotational speed, which will be the case if power is required by the power consuming device, gradually reduce the generated electric power output by the electric generator/motor.

The gradual reduction of the generated electric power output by the electric generator/motor may be continuous or step-wise. For example, values indicative of the actual engine rotational speed and corresponding values indicative of the generated electric power may be provided in a look-up table, which may then be used to control the electric generator/motor based on sensed values indicative of the actual engine rotational speed.

The electric generator/motor can be controlled to rapidly reduce its output of generated electric power and closely follow the decrease in the actual engine rotational speed, whereby the load to be driven by the combustion engine can be reduced sufficiently fast to allow the engine to continue running, and not to stall.

Hereby, the combustion engine can be allowed to remain in an operating range where it works efficiently, while at the same time fulfilling the need for power of the power consuming device.

Furthermore, various embodiments of the method of the present invention allows for the combustion engine to be dimensioned for a substantially lower peak output power than the sum of the predicted loads of the electric generator/motor and the power consuming device. This provides for a reduced CO_2-emission and a lower cost of the energy system.

The above-mentioned desired engine rotational speed may generally be selected to be an engine rotational speed at which the combustion engine has its peak efficiency, and the combustion engine may typically have an engine control system regulating the engine towards the desired engine rotational speed. Such control systems are, per se, well-known in the art.

When the load on the combustion engine fluctuates, the engine rotational speed will typically also fluctuate, the fluctuating engine rotational speed being the actual engine rotational speed. In response to such fluctuations, the engine control system will typically strive to return the engine to the desired engine rotational speed.

The method according to the present invention may further comprise the step of controlling the electric generator/motor to output a gradually increasing generated electric power, if the actual engine rotational speed is increasing towards the desired engine rotational speed, whereby efficient utilization of the power delivered by the combustion engine is provided for.

According to various embodiments thereof, the method of the present invention may advantageously further comprise the step of controlling the electric generator/motor to function as an electric motor, drawing electric power from the energy storage device and supplying mechanical power to the power consuming device if the actual engine rotational speed is lower than a predetermined threshold engine rotational speed.

Hereby, the engine can be allowed to continue to work and deliver mechanical power to the power consuming device even if the power consuming device requires more power than the combustion engine is capable of delivering, the additional mechanical power being provided by the electric generator/motor.

This allows for an even more lean dimensioning of the combustion engine, in that it may be dimensioned to provide substantially less power than may be required by the power consuming device, at least intermittently. From this follows that the energy system, and hence the hybrid vehicle, can be made even more energy-efficient and at a reduced cost.

According to a second aspect of the present invention, the above-mentioned and other objects are achieved through a controller for controlling operation of an energy system of a hybrid vehicle, the energy system comprising: a combustion engine controllable to work at a desired engine rotational speed; an electric generator/motor arranged to be driven by the combustion engine to output a generated electric power; a power consuming device arranged to be driven by the combustion engine and drivable by the electric generator/motor; and an energy storage device connected to the electric generator/motor and arranged to receive the generated electric power output by the electric generator/motor, the controller being configured to: monitor an actual engine rotational speed; and if the actual engine rotational speed decreases from the desired engine rotational speed, control the electric generator/motor to output a gradually reducing generated electric power.

The controller may be provided in the form of hardware, software or a combination thereof, and the method according to the first aspect of the present invention may be embodied in hardware in the controller, as a computer program adapted to run on a microprocessor comprised in the controller, or as a combination thereof.

For monitoring the actual engine rotational speed, the controller may have an input for acquiring data indicative of the actual engine rotational speed. The data may typically originate from a sensor sensing the actual engine rotational speed. Such sensors are well-known to the skilled person. Furthermore, the actual engine rotational speed may be monitored by directly monitoring the rotational speed of the crank shaft of the combustion engine or indirectly by monitoring other rotating parts of the energy system, such as the rotor comprised in the electric generator/motor or one or several of the shafts or other power transmitting member(s) that may mechanically connect the combustion engine with the electric generator/motor and the power consuming device.

As was described above in connection with the first aspect of the present invention, the controller may further be configured to control the electric generator/motor to function as an electric motor, drawing electric power from the energy storage device and supplying mechanical power to the power consuming device if the actual engine rotational speed is lower than a predetermined threshold engine rotational speed.

To this end, the controller may be configured to compare the actual engine rotational speed with the predetermined threshold engine rotational speed and, if the actual engine rotational speed is determined to be lower than the threshold engine rotational speed, reverse operation of the electric generator/motor. It will be well-known to the skilled person how to switch an electric generator/motor from a generator state to a motor state.

Further embodiments of, and effects obtained through this second aspect of the present invention are largely analogous to those described above for the first aspect of the invention.

Moreover, the controller according to the present invention may advantageously be included in an energy system for a hybrid vehicle, the energy system further comprising: a combustion engine controllable to work at a desired engine rotational speed; an electric generator/motor arranged to be driven by the combustion engine to output a generated electric power; a power consuming device arranged to be driven by the combustion engine and drivable by the electric generator/motor; and an energy storage device connected to the electric generator/motor and arranged to receive the generated electric power output by the electric generator/motor.

The electric generator/motor and the power consuming device may be mechanically connected to the combustion engine to be driven by the combustion engine at the actual engine rotational speed.

Moreover, the combustion engine, the electric generator/motor and the power consuming device may be arranged in an in-line arrangement and may be interconnected with shafts.

According to various embodiments, the power consuming device may be a pump for a hydraulic system, such as a hydraulic lifting system.

Furthermore, the energy system according to various embodiments of the present invention may advantageously be comprised in a hybrid vehicle, further comprising a set of driving wheels; at least one driving electric motor for driving the set of driving wheels, the electric motor being arranged to receive electric power from the energy storage device comprised in the energy system of the hybrid vehicle.

In various embodiments, the hybrid vehicle may comprise a plurality of individually controllable driving electric motors, each being arranged to drive a corresponding one of the driving wheels.

The hybrid vehicle may further comprise a hydraulic system arranged to be powered by the power consuming device comprised in the energy system of the hybrid vehicle.

In various embodiments, this hydraulic system may comprise a hydraulic lifting tool, such as an excavator bucket or a grabbing tool for a forwarder used in forestry.

According to a further aspect, the above-mentioned and other objects are also achieved by a computer program enabling execution of the steps of the method according to the first aspect of the invention when run on a controller according to the second aspect of the invention. Such a computer program may thus be a stand-alone computer program, or an upgrade, enabling an existing computer program to execute the steps of the method according to the present invention.

Brief Description of the Drawings

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing an exemplary embodiment of the invention, wherein:

Fig 1 schematically illustrates an exemplary hybrid vehicle according to an embodiment of the present invention, in the form of a forwarder for use in forestry;

Fig 2 is a block diagram schematically illustrating an embodiment of the energy system comprised in the hybrid vehicle of fig 1;

Fig 3 is a flow-chart schematically illustrating an energy system control method according to an embodiment of the present invention; and

Figs 4a-c are diagrams schematically illustrating operation of the energy system in fig 2 in an exemplary scenario.

Detailed Description of a Preferred Embodiment of the Invention

In the present detailed description, various embodiments of the control method, controller and energy system according to the present invention are mainly discussed with reference to an energy system comprised in a forwarder used in forestry. It should be noted that this by no means limits the scope of the present invention, which is equally applicable to an energy system for use in any other hybrid vehicle, such as hybrid-powered construction equipment, including excavators and dumpers.

Fig 1 schematically illustrates an exemplary hybrid vehicle in the form of a forwarder 1 for use in forestry.

The hybrid forwarder 1 comprises a cabin 2, a bed 3 for holding harvested timber, a hydraulic grabbing tool 4 for enabling the operator of the forwarder 1 to lift harvested timber from the ground to the bed 3 of the forwarder 1. The hybrid forwarder 1 is further provided with six wheels 5a-f, each being driven by an associated individually controllable electric motor (not shown in fig 1). The electric motors driving the wheels 5a-f and the hydraulic grabbing tool 4 are powered by an energy system which is not visible in fig 1, but will be described in more detail below with reference to fig 2.

Fig 2 is a block diagram schematically illustrating an embodiment of the energy system comprised in the hybrid forwarder 1 in fig 1.

With reference to fig 2, the energy system 10 comprises a combustion engine 11, which may advantageously be provided in the form of an engine running on diesel or biofuel, an electric generator/motor 12, an energy storage device 13, here being schematically indicated by a single battery, and a power consuming device in the form of a hydraulic pump 14 for powering the grabbing tool 4 of the hybrid forwarder 1 in fig 1.

As is indicated in fig 2, the combustion engine 11, the electric generator/motor 12 and the hydraulic pump 14 are mechanically connected by shafts 15, 16, which cause movable parts of the combustion engine 11, the elecric generator/motor 12 and the hydraulic pump 14 to rotate at the same rotational speed - the actual engine rotational speed, RPM_{actual}. It should be noted that the present invention is equally applicable for energy systems having an indirect mechanical connection between the different parts of the energy system 10, such as via one or several gear-boxes or similar.

As is also schematically illustrated in fig 2, the electric generator/motor 12 is electrically connected to the energy storage device 13, which in turn provides electric energy to the electric motors driving the wheels 5a-f of the forwarder 1. It should be noted that the electric generator/motor 12 may also supply electric power directly to the electric motors driving the wheels 5a-f.

To control operation of the energy system 10, the energy system 10 is provided with a controller 17, which in the exemplary embodiment schematically illustrated by fig 2 is shown as a micro-processor associated with the electric generator/motor 12.

Having now described the basic configuration of an exemplary energy system according to an embodiment of the present invention, an embodiment of the control method implemented by the controller 17 will be described below with reference to the schematic flow chart in fig 3.

Referring to fig 3, the actual engine rotational speed RPM_{actual} is monitored by the controller 17 in a first step 101. The actual engine rotational speed RPM_{actual} may be monitored by repeatedly acquiring data indicative of the actual engine rotational speed RPM_{actual}. This may, for example, be achieved by acquiring signals from one or several sensors sensing the rotational speed of the crank shaft of the combustion engine 11, the rotor of the electric generator/motor 12, the hydraulic pump 14 or any of the shafts 15, 16 mechanically connecting the main parts of the energy system 10.

In the next step 102, the monitored actual engine rotational speed RPM_{actual} is compared with a predetermined threshold engine rotational speed RPM_{th}. If the actual engine rotational speed RPM_{actual} is greater than the threshold engine rotational speed RPM_{th}, the method proceeds to step 103, where the development over time of the actual engine rotational speed RPM_{actual} is evaluated. The actual engine rotational speed RPM_{actual} may remain constant, decrease or increase.

If it is determined in step 103 that the actual engine rotational speed RPM_{actual} is constant, then the process returns to step 101 and continues to monitor the actual engine rotational speed RPM_{actual}.

If it is determined in step 103 that the actual engine rotational speed RPM_{actual} is decreasing, then the process proceeds to step 104 and controls the electric generator/motor 12 to gradually decrease the electric power output by the electric generator/motor 12. Thereafter, the process returns to step 101 and continues to monitor the actual engine rotational speed RPM_{actual}.

If it is determined in step 103 that the actual engine rotational speed RPM_{actual} is increasing, then the process proceeds to step 105 and controls the electric generator/motor 12 to gradually increase the electric power output by the electric generator/motor 12. Thereafter, the process returns to step 101 and continues to monitor the actual engine rotational speed RPM_{actual}.

If, on the other hand, it is determined in step 102 that the actual engine rotational speed RPM_{actual} is less than the threshold engine rotational speed RPM_{th}, the method proceeds to step 106 and controls the electric generator/motor 12 to function as an electric motor converting electric power drawn from the energy storage device 13 to mechanical power supplied to the hydraulic pump 14 via the shaft 16 connecting the electric generator/motor 12 and the hydraulic pump 14. Thereafter, the process returns to step 101 and continues to monitor the actual engine rotational speed RPM_{actual}.

After now having described an embodiment of the energy system control method according to the present invention in general terms, operation of the energy system described above in connection with fig 2 will be described below with reference to the schematic diagrams in figs 4a-c.

The diagram in fig 4a schematically illustrates the power consumption of the hydraulic pump 14 as a function of time for an exemplary sequence of operations of the forwarder 1 in fig 1, the diagram in fig 4b schematically illustrates the actual engine rotational speed as a function of time, and the diagram in fig 4c schematically illustrates the output of electric power from the electric generator/motor 12.

Before the first event occurring at the time t_1 indicated in figs 4a-c, the combustion engine 11 runs at the desired engine rotational speed $RPM_{desired}$, the hydraulic pump 14 consumes a very low standby power, and the electric generator/motor 12 receives practically all of the mechanical power provided by the combustion engine 11 and converts this power to generated electric power, which is output to the energy storage device 13.

As can be seen in fig 4a, there is an increase in the power consumption of the hydraulic pump 14 at time t_1, where the power consumption increases from the standby power to power P_1. This increase in the power consumption of the hydraulic pump 14 may typically result from an operator action, such as turning the forwarder 1, operating the grabbing tool 4, elevating the cabin 2 etc.

When the power consumption of the hydraulic pump 14 increases, there will momentarily be a demand for more power than the combustion engine 11 can deliver, which results in a drop in the actual engine rotational speed RPM_{actual} as is schematically illustrated in fig 4b.

The actual engine rotational speed RPM_{actual} is, as was described above in connection with the flow-chart in fig 3, monitored by the controller 17, which will control the electric generator/motor 12 to gradually reduce the generated electric power output by the electric generator/motor 12, as is schematically illustrated in fig 4c. The output of electric power from the electric generator/motor 12, and thus the mechanical power consumed by the electric generator/motor 12 will be gradually reduced until a steady-state is reached where the power provided by the combustion engine 11 corresponds to the power consumed by the electric generator/motor 12 and the hydraulic pump 14. In the presently illustrated example, this steady-state lasts until the time t_2, when the power consumption of the hydraulic pump 14 again falls back to the standby power.

As a result of the reduction of the power consumption of the hydraulic pump 14, the total power consumption of the energy system 10 falls. This allows the engine control system of the combustion engine to gradually increase the actual engine rotational speed RPM_{actual} until the desired engine rotational speed RPM_{actual} is reached, as is indicated in fig 4b.

The actual engine rotational speed RPM_{actual} is monitored by the controller 17, which, as is schematically indicated in fig 4c, controls the electric generator/motor 12 to output a gradually increasing generated electric power to the energy storage device 13.

At time t_3, there is again, as can be seen in fig 4a, an increase in the power consumption of the hydraulic pump 14, where the power consumption increases from the standby power to power P_2, which is higher than the maximum power that can be provided by the combustion engine 11. This increase in the power consumption of the hydraulic pump 14 may, for example, result from a combination of operator actions, such as simultaneously operating the grabbing tool 4 to lift a heavy load and elevating the cabin 2 etc.

When the power consumption of the hydraulic pump 14 increases, there will again momentarily be a demand for more power than the combustion engine 11 can deliver, which results in a drop in the actual engine rotational speed RPM_{actual} as is schematically illustrated in fig 4b.

In response to the decreasing actual engine rotational speed RPM_{actual}, the controller 17 will again control the electric generator/motor 12 to output a gradually reducing electric power to the energy storage device 13. Since the hydraulic pump 14 this time requires more power than the combustion engine 11 can deliver, no steady state is achieved. Instead, the actual engine rotational speed RPM_{actual} continues to drop as far as to the predetermined threshold engine rotational speed RPM_{th}. This is detected by the controller 17, which in response thereto controls the electric generator/motor 12 to function as an electric motor drawing electric power from the energy storage device 13 and supplying mechanical power to the hydraulic pump 14. Hereby, the combustion engine 11 is prevented from stalling, and the hydraulic pump 14 is provided with the mechanical power it needs from the combustion engine 11 and the electric generator/motor 12 together.

As is illustrated in fig 4a, the power consumption of the hydraulic pump 14 again falls back to the standby power at the time t_4.

As a result of the reduction of the power consumption of the hydraulic pump 14, the total power consumption of the energy system 10 falls. This allows the engine control system of the combustion engine to gradually increase the actual engine rotational speed RPM_{actual} until the desired engine rotational speed RPM_{actual} is reached, as is indicated in fig 4b.

The actual engine rotational speed RPM_{actual} is monitored by the controller 17, which, as is schematically indicated in fig 4c, controls the electric generator/motor 12 to switch back to its generator state and output a gradually increasing generated electric power to the energy storage device 13.

Although the changes in the power consumption of the hydraulic pump 14 are indicated in fig 4a as being substantially instantaneous, this is for illustrative purposes only.

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. For example, the controller 17 may be positioned anywhere in the hybrid vehicle 1, or may be comprised of distributed logic.

CLAIMS

1. A method of controlling operation of an energy system (10) for a hybrid vehicle (1), the energy system (10) comprising:

a combustion engine (11) being controlled to work at a desired engine rotational speed ($RPM_{desired}$);

an electric generator/motor (12) arranged to be driven by the combustion engine (11) to output a generated electric power;

a power consuming device (14) arranged to be driven by the combustion engine (11) and drivable by said electric generator/motor (12); and

an energy storage device (13) connected to said electric generator/motor (12) and arranged to receive the generated electric power output by the electric generator/motor (12),

wherein the method comprises the steps of:

monitoring (101) an actual engine rotational speed (RPM_{actual}); and

if the actual engine rotational speed (RPM_{actual}) decreases from said desired engine rotational speed ($RPM_{desired}$), controlling (104) said electric generator/motor (12) to output a gradually reducing generated electric power.

2. The method according to claim 1, further comprising the step of:

if the actual engine rotational speed (RPM_{actual}) increases towards said desired engine rotational speed ($RPM_{desired}$), controlling (105) said electric generator/motor (12) to output a gradually increasing generated electric power.

3. The method according to claim 1 or 2, further comprising the step of:

if the actual engine rotational speed (RPM_{actual}) is lower than a predetermined threshold engine rotational speed (RPM_{th}), controlling (106) said electric generator/motor (12) to function as an electric motor, drawing electric power from the energy storage device (13) and supplying mechanical power to the power consuming device (14).

4. A controller (17) for controlling operation of an energy system (10) of a hybrid vehicle (1), the energy system (10) comprising:

a combustion engine (11) controllable to work at a desired engine rotational speed ($RPM_{desired}$);

an electric generator/motor (12) arranged to be driven by the combustion engine (11) to output a generated electric power;

a power consuming device (14) arranged to be driven by the combustion engine (11) and drivable by said electric generator/motor (12); and

an energy storage device (13) connected to said electric generator/motor (12) and arranged to receive the generated electric power output by the electric generator/motor (12),

the controller (17) being configured to:

monitor an actual engine rotational speed (RPM_{actual}); and

if the actual engine rotational speed (RPM_{actual}) decreases from said desired engine rotational speed ($RPM_{desired}$), control said electric generator/motor (12) to output a gradually reducing generated electric power.

5. The controller (17) according to claim 4, further being configured to:

if the actual engine rotational speed (RPM_{actual}) increases towards said desired engine rotational speed ($RPM_{desired}$), control said electric generator/motor (12) to output a gradually increasing generated electric power.

6. The controller (17) according to claim 4 or 5, further being configured to:

if the actual engine rotational speed (RPM_{actual}) is lower than a predetermined threshold engine rotational speed (RPM_{th}), control said electric generator/motor (12) to function as an electric motor, drawing electric power from the energy storage device (13) and supplying mechanical power to the power consuming device (14).

7. An energy system (10) for a hybrid vehicle (1), comprising:

a combustion engine (11) controllable to work at a desired engine rotational speed ($RPM_{desired}$);

an electric generator/motor (12) arranged to be driven by the combustion engine (11) to output a generated electric power;

a power consuming device (14) arranged to be driven by the combustion engine (11) and drivable by said electric generator/motor (12);

an energy storage device (13) connected to said electric generator/motor (12) and arranged to receive the generated electric power output by the electric generator/motor (12), and

a controller (17) according to any one of claims 4 to 6.

8. The energy system (10) according to claim 7, wherein said electric generator/motor (12) and said power consuming device (14) are mechanically connected to said combustion engine (11) to be driven by the combustion engine at the actual engine rotational speed (RPM_{actual}).

9. The energy system (10) according to claim 8, wherein said combustion engine (11), said electric generator/motor (12) and said power consuming device (14) are arranged in an in-line arrangement and are interconnected with shafts (15, 16).

10. The energy system (10) according to any one of claims 7 to 9, wherein said power consuming device (14) is a pump for a hydraulic system (4).

11. A hybrid vehicle (1) comprising:

an energy system (10) according to any one of claims 7 to 9;

a set of driving wheels (5a-f);

at least one driving electric motor for driving said set of driving wheels (5a-f), said electric motor being arranged to receive electric power from the energy storage device (13) comprised in the energy system (10) of the hybrid vehicle (1).

12. The hybrid vehicle (1) according to claim 11, comprising a plurality of individually controllable driving electric motors, each being arranged to drive a corresponding one of said driving wheels (5a-f).

13. The hybrid vehicle (1) according to claim 11 or 12, further comprising a hydraulic system (4) arranged to be powered by the power consuming device (14) comprised in the energy system (10) of the hybrid vehicle (1).

14. The hybrid vehicle (1) according to claim 13, wherein said hydraulic system comprises a hydraulic lifting tool (4).

15. A computer program enabling execution of the steps of the method according to any one of claims 1 to 3 when run on a controller (17) according to any one of claims 4 to 6.

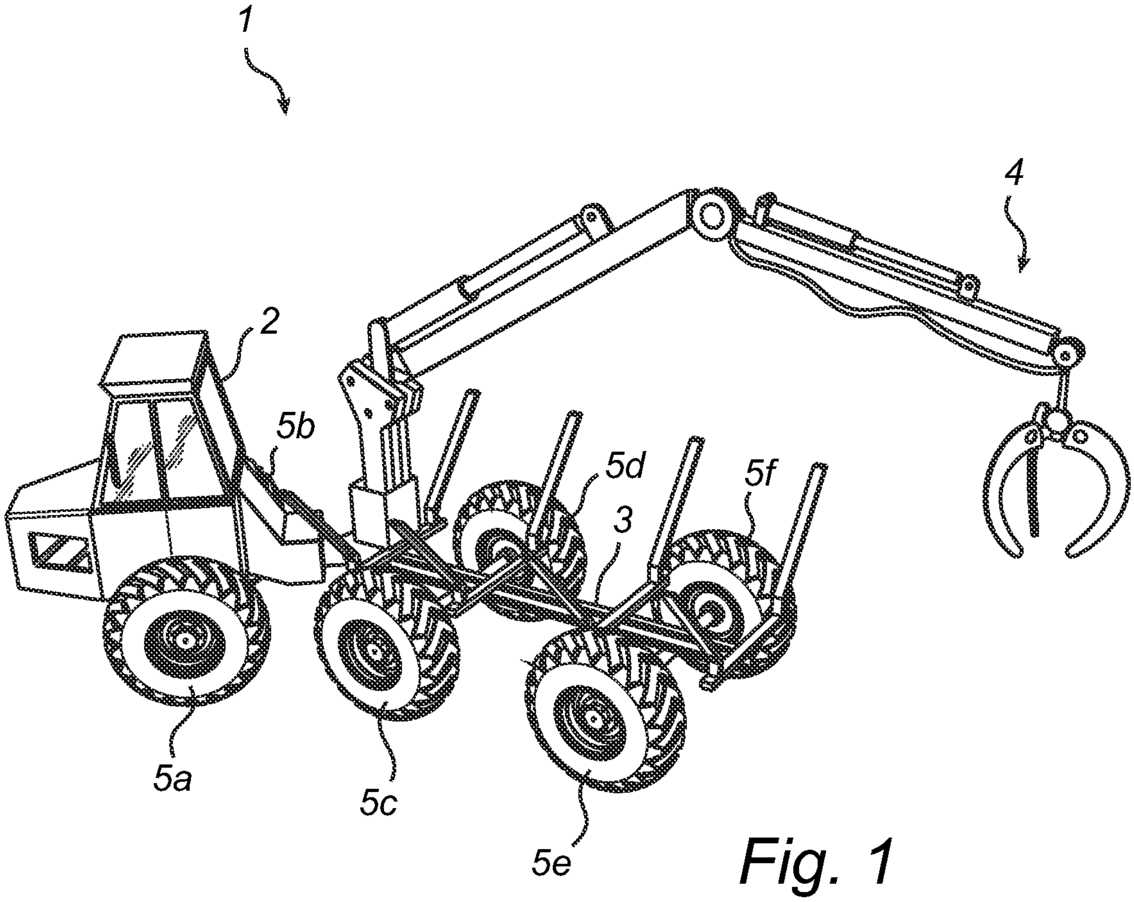

Fig. 1

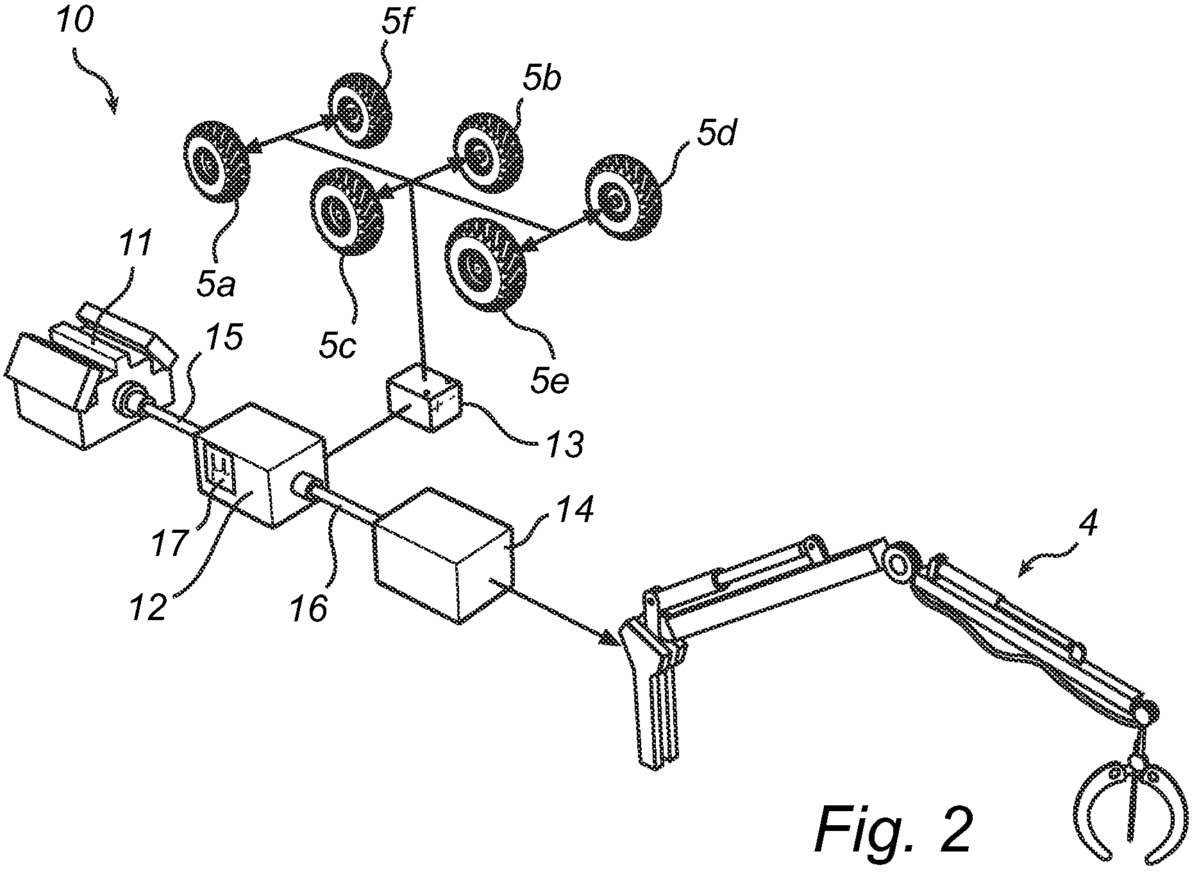

Fig. 2

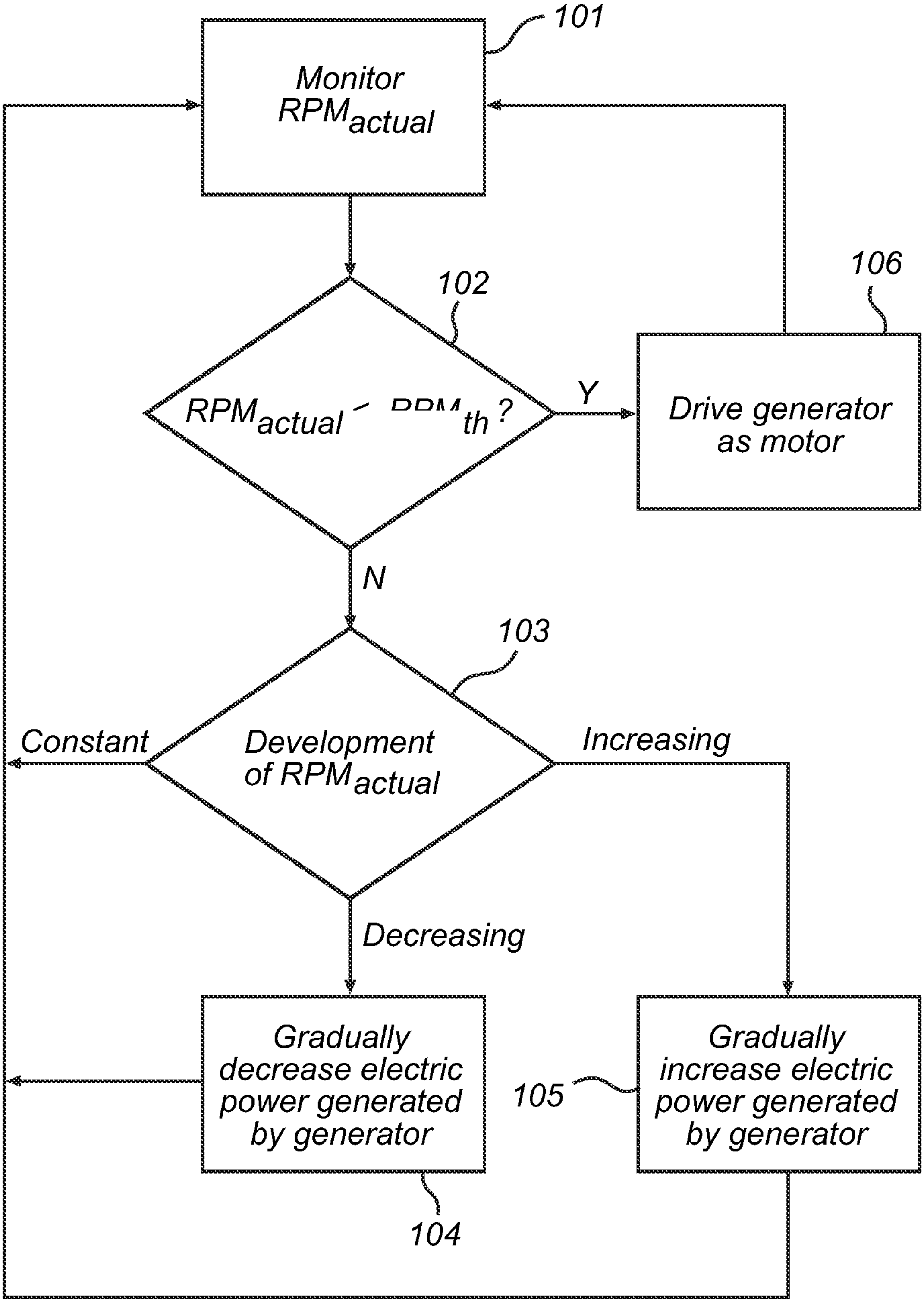
101
Monitor RPMactual
102
RPMactual
th ?
Y
106
Drive generator as motor
N
103
Development of RPMactual
Constant
Increasing
Decreasing
Gradually decrease electric power generated by generator
105
Gradually increase electric power generated by generator
104

Fig. 3

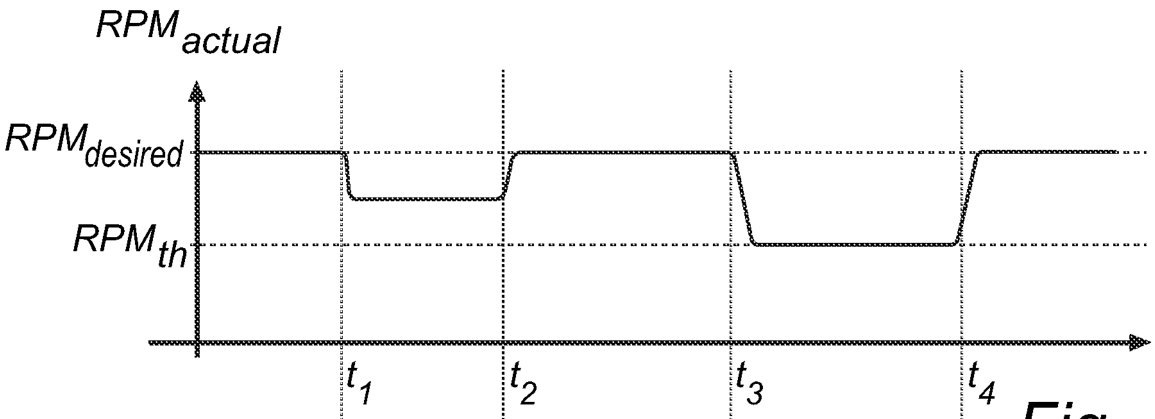

Fig. 4a

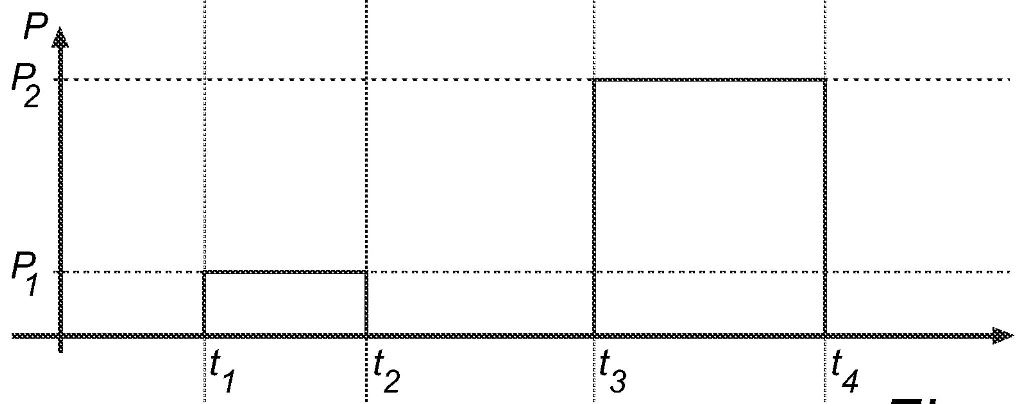

Fig. 4b

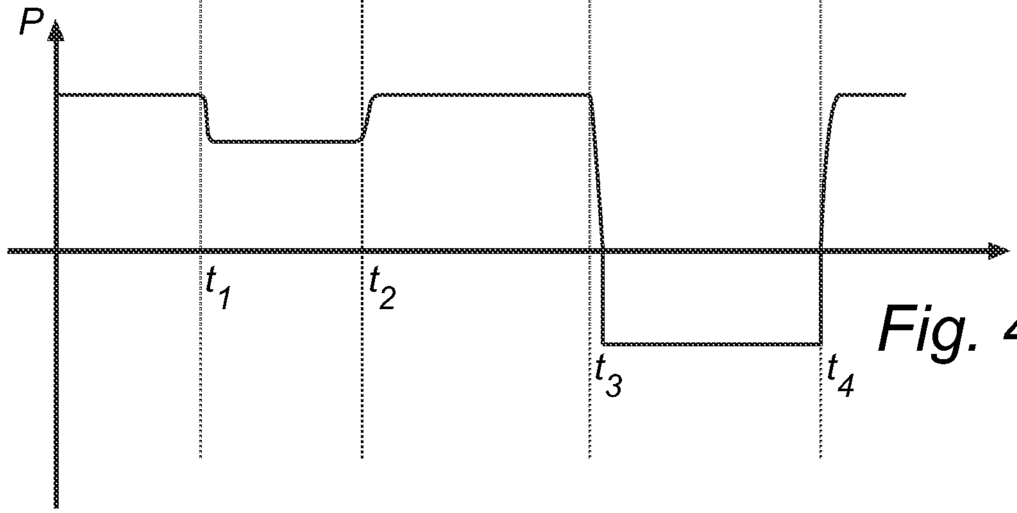

Fig. 4c

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/055711

A. CLASSIFICATION OF SUBJECT MATTER
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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)
B60W B66F

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, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/041890 A1 (VOLVO CONSTR EQUIP AB [SE]; FILLA RENO [SE]) 10 April 2008 (2008-04-10) abstract page 10, line 5 - line 14 page 11, line 15 - line 23 page 17, line 27 - page 18, line 19 claim 1	1-15
A	US 2001/052433 A1 (HARRIS DONALD B [US] ET AL) 20 December 2001 (2001-12-20) paragraphs [0048] - [0051]; figure 4	1-15

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

☒ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

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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
25 March 2010	14/04/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hulne, Serge

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2009/055711

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008041890 A1	10-04-2008	CN 101522997 A	02-09-2009
		CN 101542048 A	23-09-2009
		EP 2084335 A1	05-08-2009
		US 2010036568 A1	11-02-2010
US 2001052433 A1	20-12-2001	US 2006162973 A1	27-07-2006

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(54) **Title**: HYBRID UTILITY VEHICLE

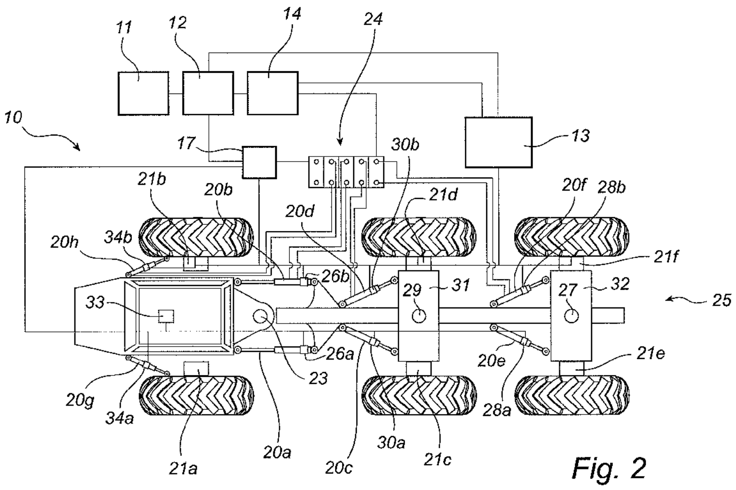

Fig. 2

(57) **Abstract**: The present invention relates to a hybrid utility vehicle (1) comprising a vehicle body (25) and at least a first and a second set of driving wheels (5a-f), each set of driving wheels comprising two wheels provided on opposite sides of the vehicle, wherein the first set of wheels (5a-b, 5e-f) is provided in front of the second set of wheels (5c-d), wherein each of the wheels of said first and second set of driving wheels (5a-d, 5e-f) is drivable by a respective drive unit (21 a-f), whereby the rotational speed of each wheel may be adjusted independently of the rotational speed of the other wheels, thereby enabling adjustment of the relative position between a wheel of the first set of driving wheels (5a-b, 5e-f) and a wheel of the second set of driving wheels (5c-d), and wherein the vehicle (1) further comprises at least one actuator (20a-h) that is arranged and configured for enabling adjustment of the relative position between said wheel of the first set of driving wheels (5a-b, 5e-f) and said wheel of the second set of driving wheels (5c-d). The present invention also relates to a method and a control unit for controlling a hybrid utility vehicle.

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HYBRID UTILITY VEHICLE

Technical Field of the Invention

The present invention relates to a hybrid utility vehicle comprising a vehicle body and at least a first and a second set of driving wheels, each set of driving wheels comprising two wheels provided on opposite sides of the vehicle, wherein the first set of wheels is provided in front of the second set of wheels, wherein each of the wheels of said first and second set of driving wheels is drivable by a respective drive unit.

The present invention also relates to a method and a control unit for controlling a hybrid utility vehicle.

Technical Background

As a part of the ongoing effort to reduce the emissions of greenhouse gases in the atmosphere, more energy-efficient vehicles are currently being developed.

One class of such vehicles is so-called hybrid vehicles, which are provided with a drive system with a combustion engine, an electric generator/motor and an energy storage device, such as batteries or capacitors. By intelligently using the energy stored in the energy storage device, the combustion engine can be run more efficiently, which leads to a reduction in the amount of CO_2 per kilometer that is emitted by the hybrid vehicle.

There exist hybrid vehicles in the form of multi-wheel driven construction equipment and other utility vehicles. Such a hybrid vehicle is e.g. disclosed in granted Swedish patent SE 526 740. The vehicle in SE 526 740 is provided with a separate motor for each wheel so that each wheel is separately driven. In order to turn the vehicle of SE 526 740 the motors are controlled to induce a relative speed between the wheels so that selected wheels move faster than others. Although generally functioning well, there is still room for improvement with regard to the driving characteristics of the vehicle in SE 526 740.

Summary of the Invention

In view of the above, a general object of the present invention is to provide for improved driving characteristics of a multi-wheel driven utility vehicle.

According to a first aspect of the invention, these and other objects are achieved through a hybrid utility vehicle comprising a vehicle body and at least a first and a second set of driving wheels, each set of driving wheels comprising two wheels provided on opposite sides of the vehicle, wherein the first set of wheels is provided in front of the second set of wheels, wherein each of the wheels of said first and second set of driving wheels is drivable by a respective drive unit, whereby the rotational speed of each wheel may be adjusted independently of the rotational speed of the other wheels, thereby enabling adjustment of the relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels, and wherein the vehicle further comprises at least one actuator that is arranged and configured for enabling adjustment of the relative position between said wheel of the first set of driving wheels and said wheel of the second set of driving wheels.

A hybrid vehicle as described above may be maneuvered in alternative manners. Firstly, it is possible to control the vehicle by alternating the relative speed between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels. Secondly, it is possible to control the vehicle by the at least one actuator. Controlling the vehicle through individually steering the wheels may be beneficial in terms of response time, energy-efficiency and easiness for the user. However, if one or several of the drive units may not drive its associated wheel to perform the desired movement, e.g. if a wheel slips or if it is obstructed by an object in the environment or if the vehicle is heavy loaded and the drive unit cannot drive the wheel to overcome the object or drive the wheel when it carries the heavy load or for any other reason, then the controlling capability may be diminished. Only controlling the vehicle through actuators may be heavy, i.e. require much force, it may not be that energy-efficient and the actuator, depending on the type of actuator, may have a longer response time than desired. However, in the present invention with its dual systems, the benefits of controlling the vehicle by independently alternating the speed of the wheels is present at the same time that the at least one actuator is provided to control the vehicle in case of e.g. slippage or obstruction of the wheels. Furthermore, if the wheels slip, the resistance for the actuator is lower than if the wheels are not slipping, and steering through the actuators does not require that much force.

Hence, providing a vehicle with a control system using both the relative speed of the wheels in combination with actuators, in accordance with the present invention, results in a hybrid utility vehicle in which the driving characteristics is improved as compared to previously known hybrid vehicles. Furthermore, by providing the possibility to in a secure manner alter the relative positions of the wheels of the vehicle, even if one or several of the wheels is e.g. obstructed or slip, other benefits, which will be described in greater detail below, may also be achieved.

It should be noted that the description that the first set of driving wheels is provided in front of the second set of driving wheels is as seen in the longitudinal extension of the vehicle body and as seen in the driving direction of the vehicle. Furthermore, it should be noted that the adjustment of the relative speed, inducing an adjustment of relative position, between a wheel in the first set of driving wheels and a wheel in the second set of driving wheels may be achieved in many alternative manners. It is for example possible to increase the speed of the wheel in the first set of driving wheels, or to decrease the speed of the wheel in the second set of driving wheels, or to increase or decrease the speed of both wheels but at a different rate.

The at least one actuator may, depending on the type of vehicle and the requirements of the vehicle be e.g. a respective actuator connected to some or all of the wheels of the vehicle in order to enable adjustment of the wheels independently. In other vehicles such as articulated vehicles, the at least one actuator may e.g. be one or more actuators provided to enable articulation of the vehicle around a central joint.

According to one exemplary embodiment, the vehicle further comprises a control unit, wherein the control unit is arranged and configured to receive an input signal indicative of a desired relative wheel position and in response to said input signal control at least one of said drive units to adjust the rotational speed of the wheel it is arranged to drive, in order to enable adjustment of the relative position between said wheel of the first set of driving wheels and said wheel of the second set of driving wheels, and to control the at least one actuator to alter the relative position between said wheel of the first set of driving wheels and said wheel of the second set of driving wheels.

The input signal may be initiated and dispatched from e.g. a driver of the vehicle or from a sensor such as a position indicator. Such sensors are well-known to the skilled person. For example, if a driver wants to steer the vehicle to turn towards one side, the driver may adjust steering means in the cabin which initiates a signal that is sent to the control unit. In other situations, it may be desirable that the relative wheel positions of the vehicle are adjusted as response to e.g. the surrounding environment. The signal may then be initiated from e.g. a position indicator indicating a change in a relative position between different parts of the vehicle. The control unit may then be arranged and configured to adjust the speed of at least one wheel and to adjust the at least one actuator in order to alter the relative position of the different parts of the vehicle.

According to one exemplary embodiment, the at least one actuator is a hydraulic actuator. Hydraulic actuators have proven to be beneficial in order to achieve the desired possibility of altering the relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels.

However, according to other exemplary embodiments, the actuator may instead be constituted of mechanical means. According to one exemplary embodiment, the mechanical means may comprise screw means that depending on how far they have been inserted into a corresponding bore alters the relative position between the wheels.

According to one exemplary embodiment, the vehicle comprises several actuators, wherein at least one actuator is associated with each wheel of the vehicle, i.e. at least one actuator is configured and arranged to alter the position of each wheel of the multi-driven vehicle. One actuator associated with one wheel provides for good possibilities of alternating the relative wheel positions. According to certain exemplary embodiments, it may be desirable to have several actuators associated with each of the wheels. This may be the situation where it is desirable to be able to alter the relative positions of the wheels in several planes.

According to one exemplary embodiment, each of the drive units is an electric motor or a hydraulic motor. Electric motors are beneficial to utilize as drive units in hybrid vehicles. Also hydraulic motors are beneficial to utilize as drive units in hybrid vehicles.

According to one exemplary embodiment, the vehicle is a vehicle in which a steering angle between at least one of the driving wheels in the first set of wheels and at least one of the driving wheels in the second set of wheels may be altered in order to affect the travel direction of the vehicle, wherein said at least one actuator is arranged and configured for adjusting said steering angle.

According to one exemplary embodiment, the vehicle is an articulated vehicle. An articulated vehicle is a vehicle with at least one pivoting joint placed between two of the sets of wheels of that vehicle. Hence, the angle between the part of the vehicle where one set of wheels is placed and a part of the vehicle where another set of wheels is places may be altered, thereby altering the angle between the two sets of wheels. The present invention may beneficially be implemented in an articulated vehicle. In that situation, when the rotational speed of a wheel is adjusted independently of the rotational speed of another wheel, thereby enabling adjustment of the relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels, the vehicle may turn around the pivoting joint and the steering angle is adjusted. If the drive units can not affect one or several of the wheels to perform the desired movement, the at least one actuator will be able to affect the adjustment of the steering angle.

According to another exemplary embodiment, at least one set of wheels of the vehicle is provided on a shaft, the extension of which may be altered in relation to the vehicle body. Hence, by altering the extension of the shaft, the angle between at least one of the driving wheels in the first set of wheels and at least one of the driving wheels in the second set of wheels may be altered in order to affect the travel direction of the vehicle. The present invention may beneficially be implemented in such a vehicle.

According to one exemplary embodiment, each of the wheels of at least one of the sets of wheels is pivotably connected to the vehicle body through a movable arm, wherein said pivotable connection allows the wheels of that at least one set of wheels to be, independently of each other, positioned at different positions along the length of the vehicle body, wherein the vertical position of a wheel in relation to the vehicle body is dependent on the position of that wheel along the length of the vehicle body.

This arrangement provides for an improvement of other driving characteristics than the ones mentioned above, i.e. prevention of lost steering capability when one or several wheels cannot be adjusted by the drive units, e.g. because the vehicle is heavy loaded or the wheel has come into contact with and been obstructed by an object in the environment or because of slippage. With this improvement, it is for example possible to maintain the vehicle body substantially horizontal when driving on e.g. sloped or uneven ground. Another improvement is the possibility to raise or lower the vehicle body, e.g. when a driver is to enter or exit the vehicle. Since the wheels are individually driven it is possible to decide to raise or lower one or several of the wheels of the vehicle in relation to the vehicle body. Hence, the vertical adjustment may take place by driving one of the wheels provided on a movable arm and maintain the other ones still, or to drive one wheel provided on a movable arm at a different speed than the other wheels. The position of that wheel along the vehicle body will then be changed, and so will the vertical position in relation to the vehicle body.

The movable arm may e.g. be a swing arm, which is fixed to the body in an articulated manner and at the other end fixed in an articulated manner to a wheel. The pivotable connection of the movable arm to the vehicle body is preferably pivotable around an axis that extends in a horizontal direction.

According to one exemplary embodiment, said vehicle comprises at least two actuators that are arranged and configured for independently adjusting the position of the wheels in said set of wheels in relation to the vehicle body.

It may be suitable to provide actuators that are connected to the movable arms so that the vertical position of the wheels may be adjusted even if a wheel may not be driven to its desired position by its associated drive unit. The actuators may also assist in maintaining the wheels in the desired position when no adjustment is to take place.

According to one exemplary embodiment, it is the wheels of the foremost set of wheels that are connected to the movable arms and hence, that are possible to vertically adjust in relation to the vehicle body.

According to a second aspect of the present invention, the above-mentioned and other objects are achieved through a method for controlling a hybrid utility vehicle comprising a vehicle body and at least a first and a second set of driving wheels, each set of driving wheels comprising two wheels provided on opposite sides of the vehicle, wherein the first set of wheels is provided in front of the second set of wheels, wherein each of the wheels of said first and second set of driving wheels is drivable by a respective drive unit, whereby the rotational speed of each wheel may be adjusted independently of the rotational speed of the other wheels, and wherein the vehicle further comprises at least one actuator that is arranged and configured for enabling adjustment of the relative position between said wheel of the first set of driving wheels and said wheel of the second set of driving wheels, said method comprises the steps of: acquiring an input signal indicative of a desired relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels; controlling at least one of the drive units associated with a wheel in the first set of driving wheels to drive that wheel with a different speed than at least one of the wheels in the second set of driving wheels, in order to achieve the desired relative position; and controlling the at least one actuator to alter the relative position between said wheel of the first set of driving wheels and said wheel of the second set of driving wheels, in order to achieve the desired relative position.

It should be noted that the method according to the present invention by no means is limited to performing the steps thereof in any particular order.

A hybrid vehicle as described above may be maneuvered in alternative manners. Firstly, it is possible to control the vehicle by alternating the relative speed between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels. Secondly, it is possible to control the vehicle by the at least one actuator. Controlling the vehicle through individually steering the wheels may be beneficial in terms of response time, energy-efficiency and easiness for the user. However, if one or several of the drive units may not drive its associated wheel to perform the desired movement, e.g. if the wheel slips or if it obstructed by an object in the environment or the vehicle is heavy loaded and the drive unit cannot drive the wheel to overcome the object or drive the wheel when it carries the heavy load or for any other reason, then the controlling capability may be diminished. Only controlling the vehicle through actuators may be heavy, i.e. require much force, it may not be that energy-efficient and the actuator, depending on the type of actuator, may have a longer response time than desired. However, in the present invention which utilizes dual systems, the benefits of controlling the vehicle by independently alternating the speed of the wheels is present and so is the effect of utilizing the at least one actuator, which will control the vehicle in case of e.g. obstruction or slippage of the wheels. Furthermore, if a wheel slip, the resistance for the actuator is lower than if the wheels are not slipping, and steering through the actuators does not require that much force. By controlling both the drive units and the actuators to achieve the same desired relative wheel position, both systems will strive towards that independently of each other. This is beneficial because the at least one actuator will then be working to achieve the desired relative wheel position, and if a drive unit for any reason may not drive the wheel it is associated with to achieve the desired position, the response for the actuator will be very short, since it is already working to achieve the desired relative wheel position.

In one exemplary embodiment, the at least one actuator is a hydraulic actuator. In that case, fluid will flow through the actuator once the control unit controls the actuator to alter a relative wheel position. Hence, if a wheel cannot be driven to its desired position by its associated drive unit, there will be a flow through the hydraulic actuator and it will be able to respond quickly.

Hence, providing a method using both the relative speed of the wheels in combination with actuators, in accordance with the present invention, results in a method of controlling a hybrid utility vehicle in which the driving characteristics is improved as compared to previously known hybrid vehicles. Furthermore, by providing the possibility to in a secure manner alter the relative positions of the wheels of the vehicle, even if one or several of the wheels is obstructed or slip, other benefits, which will be described in greater detail below, may also be achieved.

It should be noted that the method step of adjusting the relative speed, inducing an adjustment of relative position, between a wheel in the first set of driving wheels and a wheel in the second set of driving wheels may be achieved in many alternative manners. It is for example possible to increase the speed of the wheel in the first set of driving wheels, or to decrease the speed of the wheel in the second set of driving wheels, or to increase or decrease the speed of both wheels but at a different rate.

According to one exemplary embodiment, the at least one actuator and the at least one drive unit is controlled to provide the same relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels.

According to one exemplary embodiment, the method further comprises the step of: determining said desired relative wheel position from said acquired input signal.

The input signal may be initiated and dispatched from e.g. a driver of the vehicle or from a sensor such as a position indicator. For example, if a driver wants to steer the vehicle to turn towards one side, the driver may adjust steering means in the cabin which initiates a signal that is sent to the control unit. In other situations, it may be desirable that the relative wheel positions of the vehicle are adjusted as response to e.g. the surrounding environment. The signal may then be initiated from e.g. a position indicator indicating a change in a relative position between different parts of the vehicle. The control unit may then be arranged and configured to adjust the speed of at least one wheel and to adjust the at least one actuator in order to alter the relative position of the different parts of the vehicle.

According to one exemplary embodiment, said vehicle is a vehicle in which a steering angle between at least one of the driving wheels in the first set of wheels and at least one of the driving wheels in the second set of wheels may be altered in order to affect the travel direction of the vehicle, wherein the desired relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels results in a desired steering angle, wherein said method further comprises the steps of: monitoring a current steering angle, and wherein the step of the controlling at least one of said drive units and controlling said at least one actuator is performed until the current steering angle is equal to the desired steering angle.

According to one exemplary embodiment, said vehicle is an articulated vehicle. An articulated vehicle is a vehicle with at least one pivoting joint placed between two of the sets of wheels of that vehicle. Hence, the angle between the part of the vehicle where one set of wheels is placed and a part of the vehicle where another set of wheels is placed may be altered, thereby altering the angle between the two sets of wheels. The method of the present invention may beneficially be implemented to control an articulated vehicle. In that situation, when the rotational speed of a wheel is adjusted independently of the rotational speed of another wheel, thereby enabling adjustment of the relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels, the vehicle may turn around the pivoting joint and the steering angle is adjusted. If the drive units cannot affect one or several of the wheels to perform the desired movement, the at least one actuator will be able to affect the adjustment of the steering angle. The method of controlling at least one of said drive units and said at least one actuator to alter said steering angle, has the effect that the vehicle is made to turn towards one side.

According to another exemplary embodiment, at least one set of wheels of the vehicle is provided on a shaft, the extension of which may be altered in relation to the vehicle body. Hence, by altering the extension of the shaft, the angle between at least one of the driving wheels in the first set of wheels and at least one of the driving wheels in the second set of wheels may be altered in order to affect the travel direction of the vehicle. The method of the present invention may beneficially be implemented to control such a vehicle.

According to one exemplary embodiment, the method further comprises the steps of: controlling the drive unit driving the first wheel at the side of the vehicle that is opposite the side the vehicle is to turn towards to increase the rotational speed in relation to the second wheel at the side of the vehicle that is opposite the side vehicle is to turn towards, and controlling the actuator to adjust said steering angle in such a way that the distance between the first and second wheels at the side of the vehicle that is opposite the side the vehicle is to turn towards is increased.

According to one exemplary embodiment, each of the wheels of at least one of the sets of wheels is pivotably connected to the vehicle body through a movable arm, wherein said pivotable connection allows the wheels of that at least one set of wheels to be, independently of each other, positioned at different positions along the length of the vehicle body, wherein the vertical position of a wheel in relation to the vehicle body is dependent on the position of that wheel along the length of the vehicle body, wherein the desired relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels results in a desired vertical position of a pivotably connected wheel in relation to the vehicle body, and wherein at least one actuator is respectively arranged and configured for enabling adjustment of the relative position between each wheel of said set of pivotably connected driving wheels and the vehicle body, wherein the method further comprises the steps of: monitoring a current vertical position between at least one of said pivotably connected wheels and the vehicle body, wherein the step of controlling at least one of said drive units and controlling said at least one actuator is performed until the current vertical position of said wheel is equal to the desired vertical position of that wheel.

This arrangement provides for an improvement of other driving characteristics than the ones mentioned above, i.e. prevention of lost steering capability when one or several wheels cannot be adjusted by their associated drive units, e.g. because the vehicle is heavy loaded or because the wheel has come into contact with and been obstructed by an object in the environment or because of slippage. With this improvement, it is for example possible to maintain the vehicle body substantially horizontal when driving on e.g. sloped or uneven ground. Another improvement is the possibility to raise or lower the vehicle body, e.g. when a driver is to enter or exit the vehicle. Since the wheels are individually driven it is possible to decide to raise or lower one or several of the wheels of the vehicle in relation to the vehicle body. Hence, the vertical adjustment may take place by driving one of the wheels provided on a movable arm and maintain the other ones still, or to drive one wheel provided on a movable arm faster than the other wheels. The position of that wheel along the vehicle body will then be changed, and so will the vertical position in relation to the vehicle body.

The movable arm may e.g. be a swing arm, which is fixed to the body in an articulated manner and at the other end fixed in an articulated manner to a wheel. The pivotable connection of the movable arm to the vehicle body is preferably pivotable around an axis that extends in a horizontal direction.

According to one exemplary embodiment, said drive units and said at least one actuator are controlled in such a way that the difference in relative position of said wheels is determined by the drive units if the wheels rotate with the speed the control unit control the drive units to drive the wheels with.

According to one exemplary embodiment, said drive units and said at least one actuator are controlled in such a way that the difference in relative position of said wheels is determined by the drive units if none of the wheels slip.

Situations in which a wheel does not rotate with the speed the control unit control the drive units to rotate the wheel with is e.g. when the vehicle is so heavy loaded that the drive unit is not capable of driving the wheel with the desired speed or if a wheel is restricted in its movement due to objects in the terrain and the drive unit is not powerful enough to overcome that object. In these and other situations where at least one wheel does not rotate with the speed the control unit controls the drive units to drive the wheels with and in situations where at least one wheel slips, it is beneficial with the dual systems, i.e. drive units and actuators. The dual systems will, as previously described, work together to achieve the desired relative positions of the wheels. When an adjustment has been made by the at least one actuator so that the wheel once again may rotate with the desired speed or does no longer slip, the relative position of said wheels will once again be determined by the drive units. The control unit continuously monitor the wheel positions and send control signals to both the drive units and the at least one actuator. Hence, the drive units and the actuator continuously work together to control the vehicle. In each situation the drive units and the actuator strive to obtain the desired wheel position and if the drive units for some reason cannot achieve the desired wheel position, the actuator affects the wheels to achieve the desired wheel position.

As explained above, it is in certain situations desirable to utilize the drive units as a primary source of adjusting the relative positions between the wheels of the vehicle and use the actuators when one or several wheels lose their grip with the ground or is restricted in its movement for any other reason. This is for example relevant when the vehicle is to turn when standing still or when it is desired to make a vertical adjustment of at least one wheel in relation to the vehicle body when the vehicle is standing still. This is because e.g. a hydraulic system as actuator, as in one exemplary embodiment, is heavily operated when the vehicle is standing still. It may therefore be difficult to adjust the relative positions of the wheels of the vehicle, e.g. in order to turn or to vertically adjust the vehicle, using only hydraulics when the vehicle is standing still. However, once one or several wheels move with an initial speed, due to the drive units, the hydraulic system is easier to operate.

Providing this may be achieved in alternative manners. It is for example conceivable with a system in which the control unit delays the signal to the actuators somewhat in relation to the signal to the drive units. It is also conceivable with a system in which there is a delay in the actuator. According to one exemplary embodiment, the at least one actuator is a hydraulic system and the drive units are electric motors or hydraulic motors. The hydraulic system has, due to the time required to build up a sufficient pressure, a somewhat slower response time than the electric motors and the delay is therefore present in the system.

According to one exemplary embodiment, the commands are sent substantially simultaneously to both said drive units and to the at least one actuator, wherein the step of controlling the at least one actuator to alter the relative position between a wheel of the first set of driving wheels and a wheel of the second set of driving wheels to achieve the desired relative position is delayed in relation to the step of controlling at least one of the drive units to drive its respective wheel with a different speed than at least one other wheel to achieve the desired relative position.

According to one alternative embodiment, the at least one actuator is instructed to perform an operation that results in the same relative wheel position as the drive units, but at a somewhat slower rate. This may e.g. be achieved by controlling the drive units to turn e.g. left at a speed of e.g. 4 m/s and to instruct the actuator to turn left at e.g. 3.9 m/s. By this, the drive units will control the vehicle but if one or more of the wheels is e.g. obstructed or slip, the at least one actuator will continue turning the vehicle, but at a somewhat slower rate. According to one exemplary embodiment, the alternative embodiment above may be combined with providing a delay, either in the control unit or in the actuator system, as discussed above.

According to a third aspect of the present invention, the above-mentioned and other objects are achieved through a control unit for a hybrid utility vehicle in accordance with the first aspect of the present invention, wherein said control unit having an input for receiving input data, and processing circuitry configured to determine a desired relative wheel position and control at least one of said drive units and the at least one actuator to adjust the relative wheel position to said desired relative wheel position.

The control unit may be provided in the form of hardware, software or a combination thereof, and the method according to the second aspect of the present invention may be embodied in hardware in the control unit, as a computer program adapted to run on a microprocessor comprised in the control unit or as a combination thereof.

According to a fourth aspect of the present invention, the above-mentioned and other objects are achieved by a computer program enabling execution of the steps of the method according to the second aspect of the present invention when run on a control unit according to the third aspect of the present invention. Such a computer program may thus be a stand-alone computer program, or an upgrade, enabling an existing computer program to execute the steps of the method according to the present invention.

Brief Description of the Drawings

These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing an exemplary embodiment of the invention, wherein:

Figure 1 schematically illustrates, in perspective view, an exemplary hybrid vehicle according to an embodiment of the present invention, in the form of a forwarder for use in forestry;

Figure 2 schematically illustrates an embodiment of the drive system comprised in the hybrid vehicle of fig 1;

Figures 3a and 3b schematically illustrate, in top view, the hybrid vehicle turning left; and

Figures 4a and 4b schematically illustrate, in side and front view, a vertical adjustment of the vehicle body of the hybrid vehicle.

Detailed Description of an Exemplary Embodiment of the Invention

In the present detailed description, various embodiments of the hybrid utility vehicle, control method, control unit and drive system according to the present invention are mainly discussed with reference to a forwarder used in forestry. It should be noted that this by no means limits the scope of the present invention, which is equally applicable for use in any other hybrid vehicle, such as hybrid-powered construction equipment, including excavators and dumpers.

Fig 1 schematically illustrates an exemplary hybrid vehicle in the form of a forwarder 1 for use in forestry. Fig 2 is a block diagram schematically illustrating an embodiment of the drive system and the control means comprised in the hybrid forwarder 1 in fig 1.

The hybrid forwarder 1 comprises a vehicle body 25 including a cabin 2 and a bed 3 for holding harvested timber, and a hydraulic grabbing tool 4 for enabling the operator of the forwarder 1 to lift harvested timber from the ground to the bed 3 of the forwarder 1. The hybrid forwarder 1 is further provided with six wheels 5a-f, each being driven by an associated individually controllable electric motor (not shown in fig 1). Suitable components to be used are known to a person skilled in the art, and will not be further elaborated upon. The front wheels 5a-b of the vehicle are connected to the vehicle body through swing arms 22a-b, (not shown in fig 1) respectively. The electric motors driving the wheels 5a-f and the hydraulic grabbing tool 4 are powered by a drive system which is not visible in fig 1, but will be described in more detail below with reference to fig 2. The forwarder 1 also comprises actuators in the form of double-acting hydraulic cylinders 20a – h, the use of which will be described in greater detail below. The hybrid forwarder is an articulated vehicle being provided with a joint 23 between the foremost set of wheels 5a-b and the second foremost set of wheels 5c-d. The rearmost set of wheels 5e-f and the second foremost set of wheels 5c-d are each provided on a shaft 31, 32, respectively. The shafts 31, 32 are jointly connected to the vehicle body through respective joints 27, 29. In each hydraulic cylinder 20a-h is provided a respective position indicator 26a-b, 28a-b, 30a-b, 34a-b that detects the position of the cylinders and thereby the positions of the wheels of the vehicle. The vehicle also comprises a position indicator 33. The position indicator 33 is in this embodiment positioned at the bottom surface of the cabin 2 and may be a slope detecting sensor. The different types of position indicators 26a-b, 28a-b, 30a-b, 34a-b and 33 that may be employed are e.g. variable resistors or digital angle/level indicators. Another alternative is to replace the position indicators 26a-b, 28a-b, 30a-b with potentiometers provided at the respective joints 23, 27, 29 in order to detect the relative positions of the wheels of the vehicle. These and other types of position indicators that may be employed are well-known for someone skilled in the art and will therefore not be further elaborated upon.

The drive system 10 comprises a combustion engine 11, which may advantageously be provided in the form of an engine running on diesel or biofuel, an electric generator/motor 12, an energy storage device 13, here being schematically indicated by a single battery, and a hydraulic pump 14 for powering the grabbing tool 4 (not shown in fig 2) and the hydraulic cylinders 20a – h of the hybrid forwarder 1.

As is schematically illustrated in fig 2, the electric generator/motor 12 is electrically connected to the energy storage device 13, which in turn provides electric energy to the electric motors 21 a-f driving the wheels 5a-f and the hydraulic pump 14 of the forwarder 1. It should be noted that the electric generator/motor 12 may also supply electric power directly to the electric motors driving the wheels 5a-f. To control operation of the drive system 10, the drive system 10 is provided with a control unit 17, which in the exemplary embodiment schematically illustrated by fig 2 is shown as a micro-processor associated with the electric generator/motor 12.

The control unit 17 controls both operation of the motors 21a-f and the hydraulic cylinders 20a-f. The controlling of the hydraulic cylinders 20a-f is executed through valves 24 that may be operated by the control unit 17, and which are each associated with a respective hydraulic cylinder. The control unit 17 is also connected to the position indicators 26a-b, 28a-b, 30a-b, 33, 34a-b, so that the control unit may acquire signals from them and determine the vehicles position and control the motors and hydraulic cylinders as response thereto.

In fig 2, only the electric motors 21b, 21d, 21f are shown connected to the control unit 17 and the energy storage device 13. This is for sake of clarity in the drawing, and the electric motors 21a, 21c, 21f are also connected to the control unit 17 and the energy storage device 13. The same is also true for the hydraulic cylinders. In fig 2, only the hydraulic cylinders 20b, 20d, 20f, 20g are shown connected to the valves 24 but the hydraulic cylinders 20a, 20c, 20e, 20g are also connected to the valves 24.

The present invention will now be described in use during different operations and with reference to figures 3 and 4.

In figures 3a and 3b it is illustrated how the vehicle is turned towards one side, in this case the vehicle is turning left as seen in the travel direction of the vehicle. Figure 3a illustrates a situation where the vehicle 1 is driving straight forward in the longitudinal extension of the vehicle. As may be seen, all wheels 5a, 5c, 5e on the left side of the vehicle and all wheels 5b, 5d, 5f on the right side of the vehicle are aligned with each other. In the case where the wheels 5a-f are of the same diameter, the electric motors 21 a-f associated with each one of the wheels are all driving their respective wheels with the same speed. If one or more of the sets of wheels have another diameter than the other set of wheels, the speed of the set of wheels may have to be different in order to achieve a state where the vehicle 1 is moving straight forward and maintaining the respective positions between the wheels. The hydraulic actuators 20a, 20b are also positioned so that the steering angle, i.e. the angle between the first set of wheels 5a-b, and the second set of wheels 5c-d, is 180°. When driving the vehicle and desiring to turn towards one side, e.g. to the left as illustrated in figure 3b, the driver will give a signal from the cabin 2 to the control unit 17 (not shown in figure 3) to execute the turning. The control unit 17 will acquire the signal from the driver and send a signal to the motor 21b driving the right left wheel 5b of the vehicle to increase the rotational speed of that wheel, as compared to the rotational speed of the right wheel 5d positioned behind the front right wheel 5b. Furthermore, the control unit 17 will send a signal to the motor 21c driving the second foremost left wheel 5c to increase the rotational speed of that wheel, as compared to the rotational speed of the front right wheel 5a. As a consequence the vehicle body will turn about the joint 23 and the distance between the right wheels 5b and 5d will be increased and the distance between the left wheels 5a and 5c will be decreased. By this, the steering angle between the wheels is altered and the vehicle will be made to turn.

Preferably, when initiating a turn from either standing still or driving straight forward, the difference in rotational speed between the right wheels is the same as the difference in rotational speed of the left wheels. In other words, the relative speed between front right wheel 5b and second foremost right wheel 5d is equal to the relative speed between second foremost left wheel 5c and foremost left wheel 5a. In fact, when initiating a turn, the speed of the front right wheel 5b may be equal to the speed of the second foremost left wheel 5c and the speed of the second foremost right wheel 5d may be equal to the speed of the foremost left wheel 5a.

However, once the vehicle 1 has been made to initiate the desired turn, the speed of each of the wheels will be altered again, and the speed of the right wheels 5b, 5d, 5f will be increased as compared to their corresponding left wheels 5a, 5c, 5e. The reason for this is that the right wheels 5b, 5d, 5f will travel a longer distance than the left wheels 5a, 5c, 5e and in order to avoid slippage, it is beneficial that the speed of the right wheels is higher than the speed of the left wheels. In order to continue turning the speed of the fore-most right wheel 5b will still be higher than the speed of the second foremost right wheel 5d and the speed of the second foremost left wheel 5c will be higher than the speed of the foremost left wheel 5a. Preferably, the difference in rotational speed between the right wheels is the same as the difference in rotational speed of the left wheels. In other words, the relative speed between front right wheel 5b and second foremost right wheel 5d is equal to the relative speed between second foremost left wheel 5c and foremost left wheel 5a, even though the right wheels are driven with a higher speed than the left wheels. For example, when turning as quickly as possible, the speed of the outer wheels may be twice the speed of the inner wheels. The relative speed of each of the wheels is calculated and determined by the control unit 17, based on the input from position indicators 26a-b, 28a-b, 30a-b (not shown in figs 3). Hence, the relative speed of each wheel is continuously adjusted when the vehicle is operated, depending on signals from the driver's cabin and signals from the position indicators.

At the same time the control unit 17 controls the respective motors, it will also send a signal to the valves 24 controlling the flow of fluid to the hyd-raulic actuators 21a-g. In order for the vehicle to initiate a turn to the right, the valves associated with the hydraulic cylinders 21 a-d will be opened so that fluid may flow to these cylinders. The cylinders are double-acting hydraulic cylinders. Hence, when fluid enters the cylinders 20a and 20c so that these are made to retract, the distance between the wheels 5a and 5c will be decreased and when fluid is made to enter the cylinders 20b and 20d so that these are made to expand, the distance between the wheels 5b and 5d will be increased. By this movement of the hydraulic cylinders, the steering angle between the foremost and second foremost wheels 5a-d is altered and the vehicle will be made to turn.

The signal may be sent simultaneously to both the motors and the hydraulic system, but there is a short delay in the hydraulic system before it affects the relative position of the wheels. This is due to the fact that it takes time to build pressure in the hydraulic cylinders. Therefore, when the vehicle is to turn, the electric motors will initiate the alteration of the steering angle, i.e. turn the vehicle, and fluid will be pumped through the hydraulic cylinders but without exerting any pressure. This is because the wheels will be made to turn by the drive units and there will therefore be no resistance from them when the actuators expand and retract. However, if one or several of the wheels cannot perform the desired adjustment, e.g. due to that the vehicle is so heavy loaded that the drive unit cannot drive the wheel with the desired speed, or that an object or unevenness in the terrain obstructs the movement of the wheel and the drive unit cannot drive the wheel to overcome that obstruction or due to slippage of a wheel, the hydraulic cylinders will, due to their respective expansion or retraction, maintain or continue to alter the steering angle and the turning will be effected even though one or several wheels are not capable of performing the desired adjustment.

In the illustrated embodiment with a six-wheeled vehicle, the rearmost set of wheels 5e-f will be controlled to act mirror-inverted in relation to the second foremost set of wheels 5c-d. Hence, if the position indicators 26a-b, 30a-b signals to the control unit 17 that the shaft 31 is inclined e.g. 10° in relation to the longitudinal extension of the vehicle body with the right wheel 5d in front of the left wheel 5c (as is illustrated in fig 3b), the control unit 17 will control the motors 21e-f and the hydraulic cylinders 20e-f to incline the shaft 32 10° in relation to the longitudinal extension of the vehicle body with the left wheel 5e in front of the right wheel 5f.

The turning of the vehicle has been illustrated in a situation where the vehicle is to turn left when it is moving forward. However, the same reasoning applies also when the vehicle is to turn in any other direction. For example, if turning right, the control unit will perform the same operations but mirror-inverted. If the vehicle is instead moving in the reverse direction, i.e. back-wards, the rearmost set of wheels 5e-f will be controlled and act in the manner described above for the foremost set of wheels 5a-b and the foremost set of wheels 5a-b will be controlled and act in the manner described above for the rearmost set of wheels 5e-f.

In figures 4a and 4b it is illustrated how the vertical position of the cabin 2 of the vehicle may be altered. This may e.g. be beneficial when driving in sloped or uneven terrain or when entering or exiting the vehicle. As given above, the wheels 5a-b of the foremost set of wheels are each connec-ted to the vehicle body 25 through movable arms 22a-b. The movable arms 22 a-b are pivotably connected to the vehicle body 25 through double-acting hydraulic cylinders 20g-h, respectively. The hydraulic cylinders 22g-h are controlled by the control unit 17 and hold the respective wheels 5a-b in a desired position in relation to the vehicle body 25. If the hydraulic cylinders 22g-h did not do that, then the front part of the vehicle would fall to the ground due to the movable arms 22a-b.

As is best seen in fig 4b, each of the movable arms may rotate around a respective axis A, which is substantially horizontal. The movable arms 22 a-b are also pivotably connected to the center of each of the wheels, respect-tively, and may rotate around an axis B which also is substantially horizontal and extends through the center of each of the wheels 5a-b. Due to the possibility for the arms 22a-b to rotate in relation to the vehicle body 25, the vertical position of the wheels 5a-b may be adjusted in relation to the vehicle body. Hence, the vertical position of each of the wheels 5a-b in relation to the vehicle body is dependent on the position of the respective wheel along the length of the vehicle body.

In fig 4b, the vehicle 1 is seen from the front of the vehicle and as may be seen the left wheel 5a is positioned lower in relation to the vehicle body than the right wheel 5b. In order to achieve this adjusted vertical position of either one of the wheels, the control unit 17 controls the wheel that is to be lowered in relation to the vehicle body 25 to drive forward and at the same time controls the valves 24 so that fluid is being passed to the corresponding hydraulic cylinder. The fluid makes the cylinder, in figs 4 the cylinder 20g, expand and thereby effect the desired movement of the movable arm 22a. As is best seen in fig 4a, the left wheel 5a, that is positioned lower than the right wheel 5b in relation to the vehicle body 25, is also positioned forward of the right wheel 5b as seen in the longitudinal extension of the vehicle body.

If one desires to raise one of the wheels, the control unit instead controls the motor driving that wheel to drive it rearwards and at the same time controls the valves 24 to retract the cylinder associated with that wheel.

As described above for the turning of the vehicle, the control unit 17 may send the signal simultaneously or substantially simultaneously to the electric motor and the hydraulic system, but due to a certain delay in the hydraulic system, it is the motor that will initiate the vertical adjustment. The hydraulic system will however affect the movement of the wheel and the movable arm if the wheel starts slipping or if the electric motor for any other reason, e.g. that the movement of a wheel is obstructed, is not capable of performing the desired adjustment.

It has been illustrated how a vertical adjustment of one side of the vehicle takes place. However, performing the same operation on both of the wheels of the front set of wheels makes it possible to raise or lower the entire cabin 2 of the vehicle.

The signal to the control unit 17 to control the vertical adjustment of the vehicle body may either come from a driver in the cabin or from the position indicator 33. The position indicator 33 may, as mentioned above, be a slope detecting sensor, provided to detect that the vehicle body slopes in the longitudinal and/or transversal direction of the vehicle.

The person skilled in the art realizes that the present invention by no means is limited to the preferred embodiments described above. For example, the control unit 17 may be positioned anywhere in the hybrid vehicle 1, or may be comprised of distributed logic.

Furthermore, the present invention has been described in a six-wheel vehicle, but is equally applicable to any other multi-wheel vehicles. For example, an articulated four-wheel vehicle using the present invention will function as described above, but without operation of the rearmost set of wheels. The vehicle does also not have to be an integrated vehicle. Instead, it may be e.g. a vehicle with a trailer, wherein the wheels and actuators of the vehicle and the trailer are configured and arranged in accordance with the present invention.

Furthermore, the actuators 20g-h for effecting vertical adjustment of the vehicle body has been illustrated as extending forwards from the vehicle. However, they may be provided in other manners as well. In the disclosed embodiment, only the foremost set of wheels has been illustrated as being arranged for enabling vertical adjustment. However, it is possible to provide all wheels of the vehicle with this arrangement.

CLAIMS

1. A hybrid utility vehicle (1) comprising a vehicle body (25) and at least a first and a second set of driving wheels (5a-f), each set of driving wheels comprising two wheels provided on opposite sides of the vehicle, wherein the first set of wheels (5a-b, 5e-f) is provided in front of the second set of wheels (5c-d),

wherein each of the wheels of said first and second set of driving wheels (5a-d, 5e-f) is drivable by a respective drive unit (21a-f), whereby the rotational speed of each wheel may be adjusted independently of the rotational speed of the other wheels, thereby enabling adjustment of the relative position between a wheel of the first set of driving wheels (5a-b, 5e-f) and a wheel of the second set of driving wheels (5c-d), and

wherein the vehicle (1) further comprises at least one actuator (20a-h) that is arranged and configured for enabling adjustment of the relative position between said wheel of the first set of driving wheels (5a-b, 5e-f) and said wheel of the second set of driving wheels (5c-d).

2. A hybrid utility vehicle according to claim 1, wherein the vehicle (1) further comprises a control unit (17), wherein the control unit (17) is arranged and configured to receive an input signal indicative of a desired relative wheel position and in response to said input signal control at least one of said drive units (21a-d) to adjust the rotational speed of the wheel it is arranged to drive, in order to enable adjustment of the relative position between said wheel of the first set of driving wheels (5a-b) and said wheel of the second set of driving wheels (5c-d), and to control the at least one actuator (20a-g) to alter the relative position between said wheel of the first set of driving wheels (5a-b, 5e-f) and said wheel of the second set of driving wheels.

3. A hybrid utility vehicle according to any one of claims 1 or 2, wherein the at least one actuator (20a-h) is a hydraulic actuator.

4. A hybrid utility vehicle according to any one of the preceeding claims, wherein each of the drive units (21a-f) is an electric motor or a hydraulic motor.

5. A hybrid utility vehicle according to any one of the preceeding claims, wherein the vehicle (1) is a vehicle in which a steering angle between at least one of the driving wheels in the first set of wheels (5a-b, 5e-f) and at least one of the driving wheels in the second set of wheels (5c-d) may be altered in order to affect the travel direction of the vehicle (1), wherein said at least one actuator (20a-f) is arranged and configured for adjusting said steering angle.

6. A hybrid utility vehicle according to any one of the preceeding claims, wherein each of the wheels (5a-b) of at least one of the sets of wheels is pivotably connected to the vehicle body through a movable arm (22a-b), wherein said pivotable connection allows the wheels of that at least one set of wheels to be, independently of each other, positioned at different positions along the length of the vehicle body (25), wherein the vertical position of a wheel in relation to the vehicle body (25) is dependent on the position of that wheel along the length of the vehicle body (25).

7. A hybrid utility vehicle according to claim 6, wherein said vehicle comprises at least two actuators (20g-h) that are arranged and configured for independently adjusting the position of the wheels (5a-b) in said set of wheels in relation to the vehicle body (25).

8. A method for controlling a hybrid utility vehicle comprising a vehicle body (25) and at least a first and a second set of driving wheels, each set of driving wheels comprising two wheels provided on opposite sides of the vehicle, wherein the first set of wheels (5a-b, 5e-f) is provided in front of the second set of wheels (5c-d),

wherein each of the wheels of said first and second set of driving wheels (5a-f) is drivable by a respective drive unit (21a-f), whereby the rotational speed of each wheel may be adjusted independently of the rotational speed of the other wheels, and

wherein the vehicle further comprises at least one actuator (21a-h) that is arranged and configured for enabling adjustment of the relative position between said wheel of the first set of driving wheels (5a-b, 5e-f) and said wheel of the second set of driving wheels,

said method comprises the steps of:

acquiring an input signal indicative of a desired relative position between a wheel of the first set of driving wheels (5a-b, 5e-f) and a wheel of the second set of driving wheels (5c-d);

controlling at least one of the drive units (21a-b, 21e-f) associated with a wheel in the first set of driving wheels (5a-b, 5e-f) to drive that wheel with a different speed than at least one of the wheels in the second set of driving wheels (5c-d), in order to achieve the desired relative position, and

controlling the at least one actuator (21a-h) to alter the relative position between said wheel of the first set of driving wheels (5a-b, 5e-f) and said wheel of the second set of driving wheels (5c-d), in order to achieve the desired relative position.

9. A method according to claim 8, wherein the method further comprises the step of:

determining said desired relative wheel position from said acquired input signal.

10. A method according to any one of claims 8 or 9, wherein said vehicle is a vehicle in which a steering angle between at least one of the driving wheels in the first set of wheels (5a-b, 5e-f) and at least one of the driving wheels in the second set of wheels (5c-d) may be altered in order to affect the travel direction of the vehicle (1), wherein the desired relative position between a wheel of the first set of driving wheels (5a-b, 5e-f) and a wheel of the second set of driving wheels (5c-d) results in a desired steering angle,

wherein said method further comprises the steps of:

monitoring a current steering angle, and

wherein the step of the controlling at least one of said drive units (21a-f) and controlling said at least one actuator (20a-f) is performed until the current steering angle is equal to the desired steering angle.

11. A method according to any one of claims 8 – 10, wherein each of the wheels of at least one of the sets of wheels is pivotably connected to the vehicle body through a movable arm (22a-b), wherein said pivotable connection allows the wheels of that at least one set of wheels to be, independently of each other, positioned at different positions along the length of the vehicle body (25), wherein the vertical position of a wheel in relation to the vehicle body is dependent on the position of that wheel along the length of the vehicle body, wherein the desired relative position between a wheel of the first set of driving wheels (5a-b, 5e-f) and a wheel of the second set of driving wheels results in a desired vertical position of a pivotably connected wheel in relation to the vehicle body, and wherein at least one actuator (20g-h) is respectively arranged and configured for enabling adjustment of the relative position between each wheel of said set of pivotably connected driving wheels and the vehicle body,

wherein the method further comprises the steps of:

monitoring a current vertical position between at least one of said pivotably connected wheels and the vehicle body,

wherein the step of controlling at least one of said drive units (21a-b) and controlling said at least one actuator (20g-h) is performed until the current vertical position of said wheel is equal to the desired vertical position of that wheel.

12. A method according to any one of claims 8 – 11, wherein said drive units (21a-f) and said at least one actuator (20a-h) are controlled in such a way that the difference in relative position of said wheels is determined by the drive units (21a-f) if the wheels rotate with the speed the control unit (17) control the drive units (21 a-f) to drive the wheels with.

13. A method according to any one of claims 8 – 12, wherein said drive units (21a-f) and said at least one actuator (20a-h) are controlled in such a way that the difference in relative position of said wheels is determined by the drive units (21a-f) if none of the wheels slip.

14. A control unit for a hybrid utility vehicle in accordance with any one of claims 1 – 7, wherein said control unit (17) having an input for receiving input data, and processing circuitry configured to determine a desired relative wheel position and control at least one of said drive units and the at least one actuator to adjust the relative wheel position to said desired relative wheel position.

15. A computer program enabling execution of the steps of the method according to any one of claims 8 – 13 when run on a control unit according to claim 14.

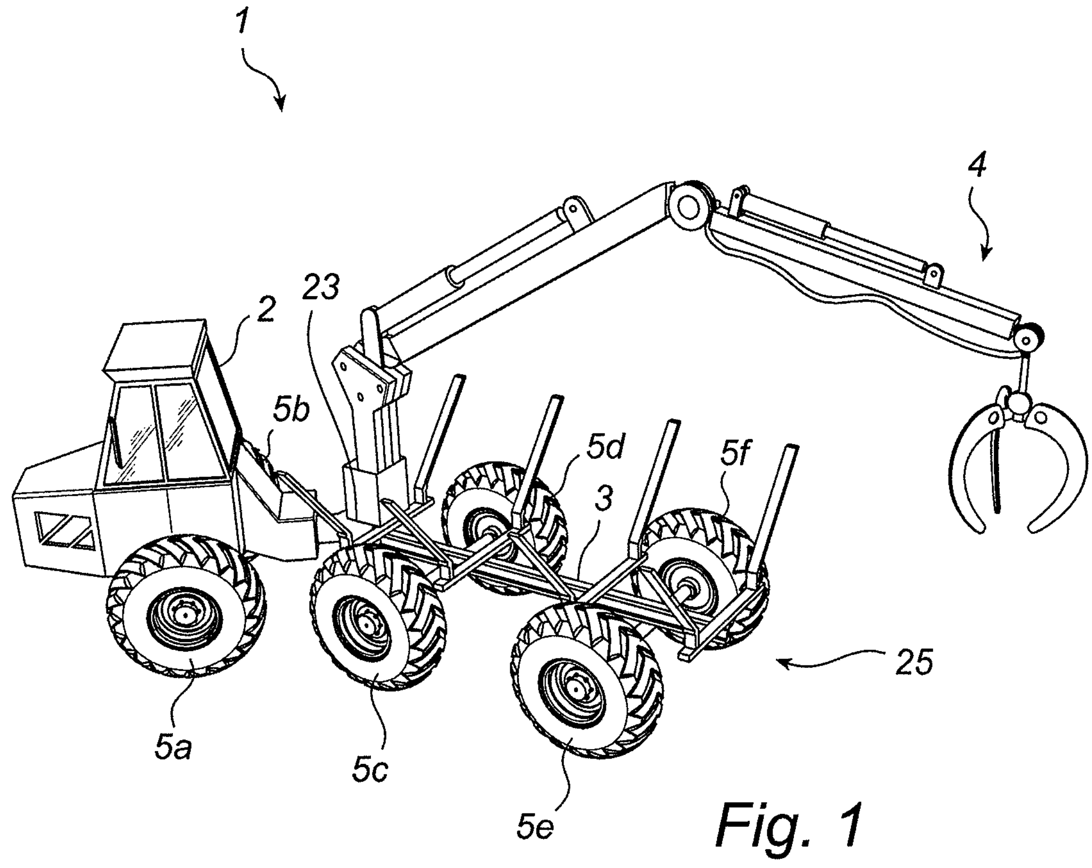
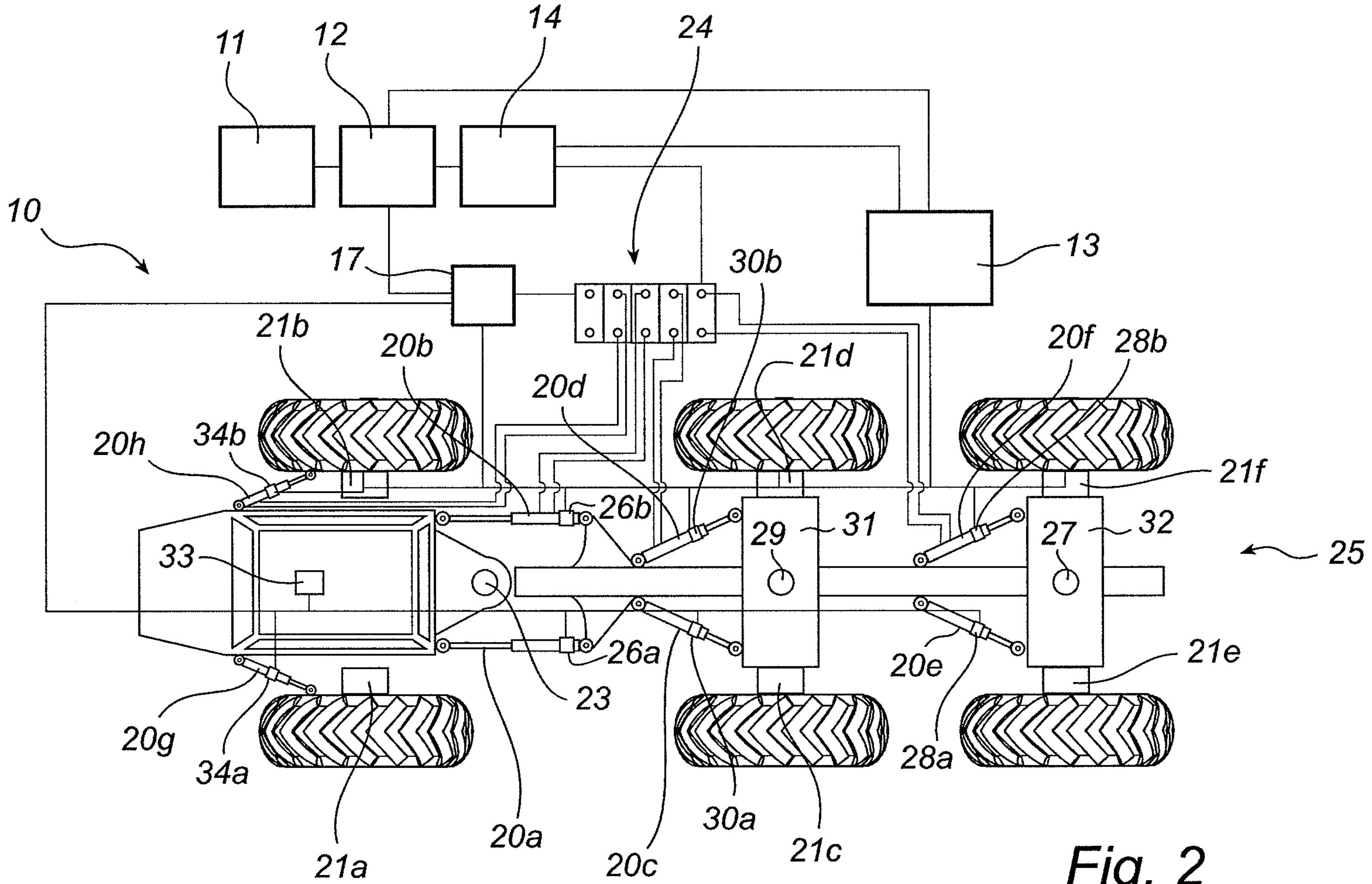


Fig. 1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12
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24
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31
27
32
25
21f
33
23
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20e
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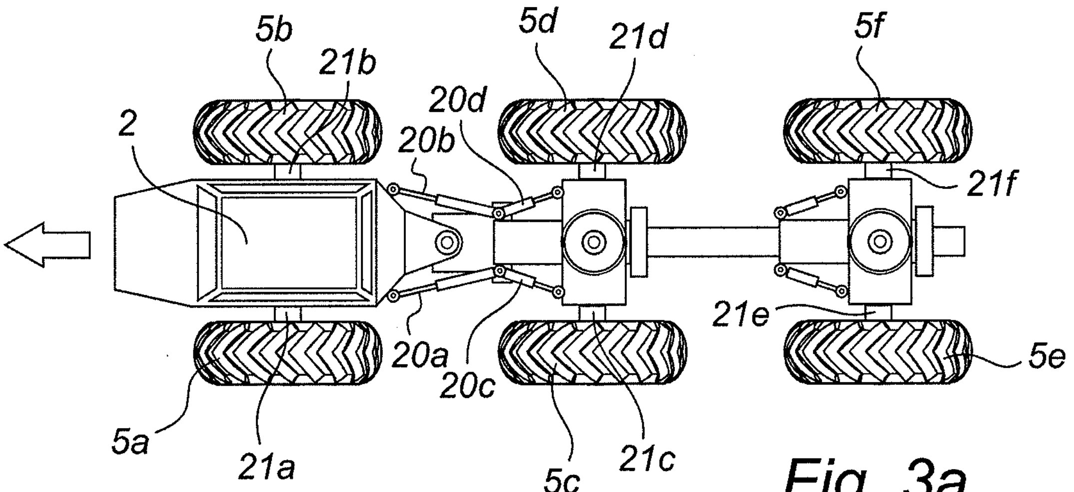
28a
30a
21a
20a
20c
21c

Fig. 2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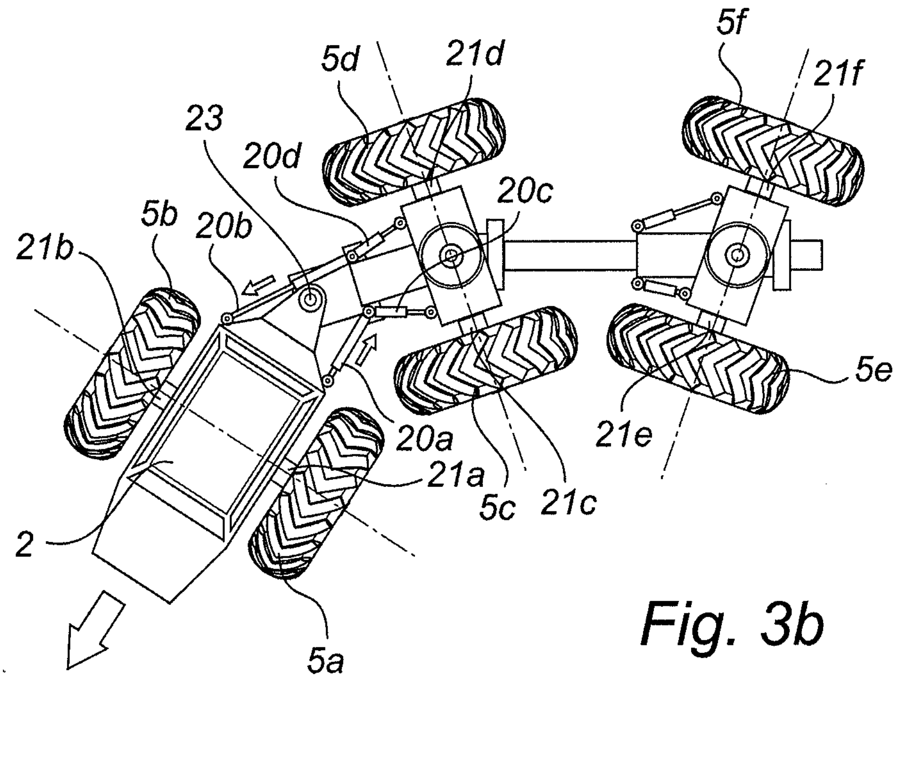
21b
2
20d
20b
5d
21d
5f
21f
21e
5e
20a
20c
5a
21a
5c
21c

Fig. 3a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5f
21f
23
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20c
5b
20b
21b
20a
21a
5c
21c
21e
5e
2
5a

Fig. 3b

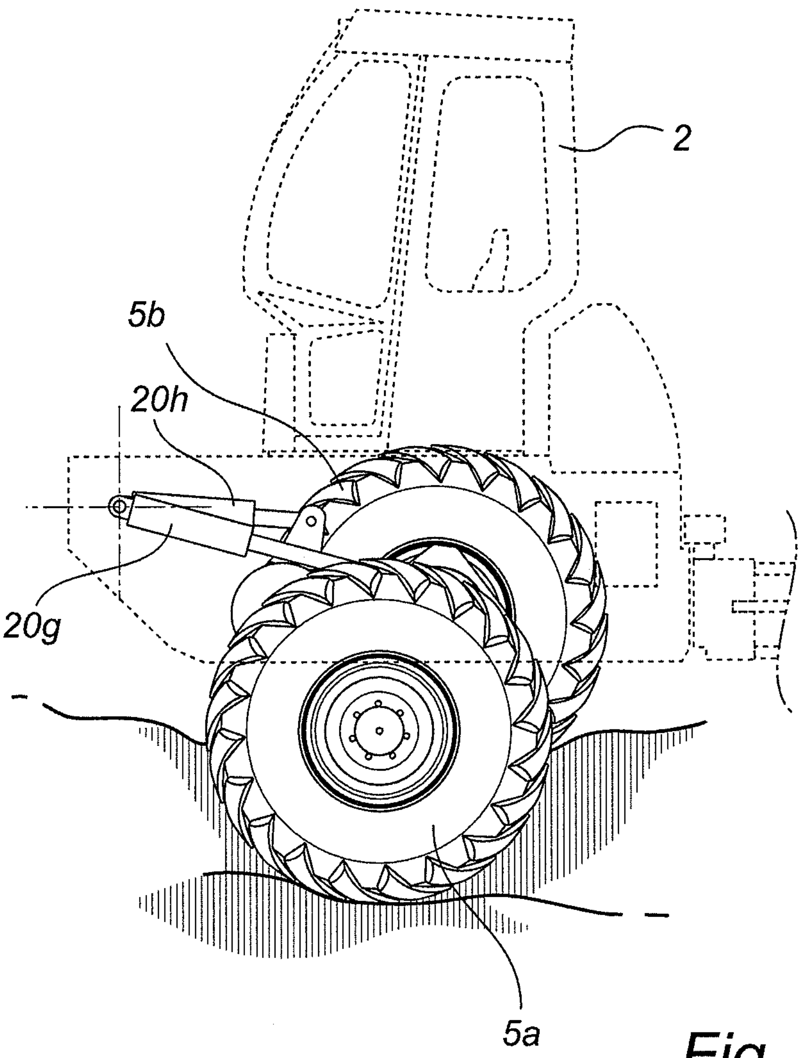

Fig. 4a

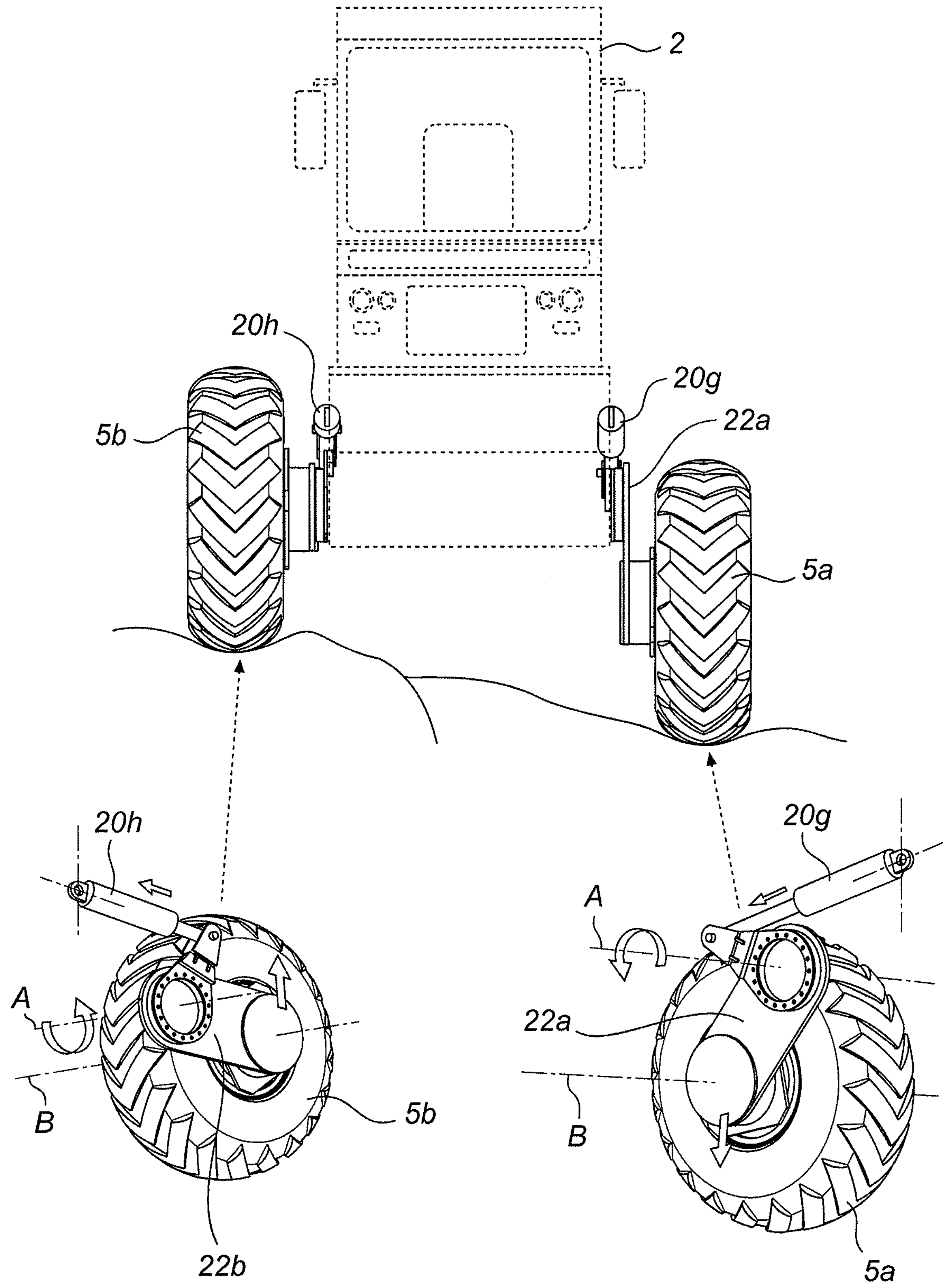

Fig. 4b

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/056657

A. CLASSIFICATION OF SUBJECT MATTER
INV. B62D12/00 B62D11/04

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)
B62D

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.
X	US 2007/017717 A1 (KUPER WILLIAM F [US] ET AL) 25 January 2007 (2007-01-25)	1,3-5, 8-9,12, 14-15
Y	paragraphs [0057] - [0059], [0068] - [0074], [0082]; figures 10,11,17,18	2,6-7, 10-11,13
Y	US 2004/093139 A1 (WILDEY ALLAN J [CA] ET AL) 13 May 2004 (2004-05-13)	2,10,13
A	paragraphs [0018], [0026], [0027], [0038], [0039]; figure 1	1,3-4, 8-9
Y	DE 91 07 488 U1 (HARTIG, JÜRGEN) 29 August 1991 (1991-08-29)	6-7,11
A	page 7, line 23 - page 10, last line; figures 1, 2a page 13, line 13 - line 31; figure 4 claims 1,3,4,6,9,10	1-5,8, 10,12, 14-15

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

☒ See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 February 2010	18/02/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016	Kulozik, Ehrenfried

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2009/056657

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 2004093139 A1	13-05-2004	NONE	
DE 9107488 U1	29-08-1991	DE 4219876 A1	24-12-1992

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13 February 2020 (13.02.2020)

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WO 2020/165819 A1

(54) **Title:** A HYBRID AGRICULTURAL VEHICLE

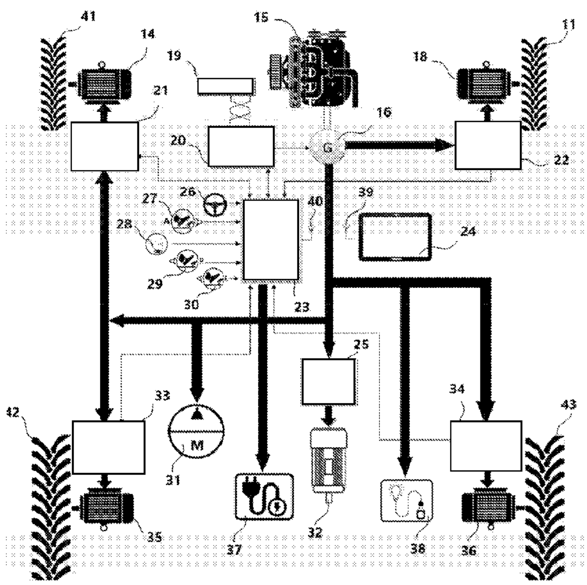

FIG. 3

(57) **Abstract:** The present invention relates to a hybrid agriculture vehicle. The hybrid agriculture vehicle, comprising of a chassis; an internal combustion engine; an alternator; a plurality of front and rear traction motors which are controlled by a plurality of torque management controllers; a plurality of front and rear end wheels; a gear arrangement; and a power take off system with a power take off controller wherein, each of the traction motor is fitted to each of the wheel without any gear arrangement utilizing electric power generated by the alternator coupled with the internal combustion engine to reduce frictional losses, and the power take off controller controls output characteristics is no more dependent on the engine and the hybrid vehicle characteristics.

[Continued on next page]

SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

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A HYBRID AGRICULTURAL VEHICLE

FIELD OF THE INVENTION

[001] The present invention relates to a hybrid agricultural vehicle having an internal combustion engine that operates with diesel or gasoline or compressed natural gas or any other required fuel wherein, the electric motor is fitted to the individual wheels to drive the vehicle utilizing the electric power generated by the alternator coupled with the internal combustion engine.

BACKGROUND OF THE INVENTION

[002] The hybrid agricultural vehicles comprising of an internal combustion engine are already known in the prior art. The hybrid agricultural vehicle, more specifically, a tractor is a multi-utility machinery often used in the rugged environment. The mandatory character of such state of the art agriculture vehicles is that they are built with ruggedness.

[003] In the existing prior art, the agriculture vehicle comprises of the internal combustion engine coupled with a transmission system where the transmission system is an orderly arrangement of gears, built for the function of manipulating the speed and torque characteristic to the requirement. The output of the transmission system is fed to the differential gear, the differential gear splits the power between the rear wheels in case of a rear wheel drive vehicle or between all four wheels in case of a four wheel drive machine.

[004] The components such as the engine, transmission and the rear axle which has the differential gear acts as the chassis. The arrangement absorb the imposed vibrations at the time of operation of the vehicle. The support systems for the engine operation such as the fuel system, exhaust system and the cooling system are assembled around the engine.

[005] The tractor with a special component i.e. a power take-off system is already known. The power take-off system in the tractor is a shaft which runs the length of the tractor from the engine to the rear or front of the tractor. Thus, making the output characteristics of the power take-off systems to be strictly dependent on the engine characteristics.

[006] The existing knowledge and the arrangement works well but there are some paths of improvement in terms of performance of the vehicle, meaning the mating components in transmission and wheel assembly results in reduced efficiency owing to frictional losses. There is also scope of improvement in the emission characteristics of the vehicle with a better optimized machinery and will also result in optimized performance.

[007] Thus, a solution is required to reduce such frictional losses and improve emission characteristics. The present invention provides one such solution by providing the hybrid agricultural vehicle having the internal combustion engine with the features and the electric motor fitted to the individual wheels to drive the vehicle by utilizing the electric power generated by the alternator coupled with the internal combustion engine.

SUMMARY OF THE INVENTION

[008] In accordance with one aspect of the present invention, a hybrid vehicle comprising of: a chassis; an internal combustion engine mounted on the chassis which is controlled by an engine electronic control unit; an alternator, mechanically coupled with the internal combustion engine; a plurality of front tractions motors and rear traction motors which is controlled by a plurality of torque management controllers; and a plurality of front and rear end wheels.

[009] Each of the traction motor is fitted to each of the wheel without any gear arrangement utilizing electric power generated by the alternator coupled with the internal combustion engine to reduce frictional losses.

[0010] In accordance with the second aspect of the invention, the hybrid vehicle comprises of a power take off system with a power take off controller wherein the power take off controller controls output characteristics are no more dependent on the internal combustion engine and the hybrid vehicle characteristics.

[0011] Other objects and advantages of the present invention will become apparent from the following description taken in connection with the accompanying drawings, wherein, by way of illustration and example, the aspects of the present invention are disclosed.

BRIEF DESCRIPTION OF DRAWINGS

[0012] The present invention will be better understood after reading the following detailed description of the presently preferred aspects thereof with reference to the appended drawings, in which the features, other aspects and advantages of certain exemplary embodiments of the invention will be more apparent from the accompanying drawings in which:

[0013] FIG.1 shows the schematic view of the hybrid agricultural vehicle.

[0014] FIG.2 shows the electric motor and wheel assembly with no intermediate gear arrangement of the hybrid agricultural tractor.

[0015] FIG.3 shows the overall block diagram of the hybrid agricultural vehicle.

[0016] FIG.4 shows the block diagram for the compressed natural gas-electric operation in the hybrid agricultural vehicle.

[0017] FIG.5 compressed natural gas fuel system assembly in the hybrid agricultural vehicle.

DETAILED DESCRIPTION OF THE INVENTION

[0018] The following description describes various features and functions of the disclosed device and methods with reference to the accompanying figures. In the figures, similar symbols identify similar components, unless context dictates otherwise. The illustrative aspects described herein are not meant to be limiting. It may be readily understood that certain aspects of the disclosed system, method and apparatus can be arranged and combined in a wide variety of different configurations, all of which are contemplated herein.

[0019] These and other features and advantages of the present invention may be incorporated into certain embodiments of the invention and will become more fully apparent from the following description and claims or may be learned by the practice of the invention as set forth hereinafter.

[0020] Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the embodiments described herein can be made without departing from the scope of the invention. In addition, descriptions of well-known functions and constructions are omitted for clarity and conciseness.

[0021] The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used to enable a clear and consistent understanding of the invention. Accordingly, it should be apparent to those skilled in the art that the following description of exemplary embodiments of the present invention are provided for illustration purpose only and not for the purpose of limiting the invention.

[0022] It is to be understood that the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise.

[0023] It should be emphasized that the term “comprises/comprising” when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof.

[0024] As per the preferred embodiment of the present invention, a hybrid agriculture vehicle comprising of: a chassis acting as a mounting base; an internal combustion engine mounted on the chassis which is controlled by an engine electronic control unit; an alternator, mechanically coupled with the internal combustion engine; a plurality of front and rear traction motors which are controlled by a plurality of torque management controllers; a plurality of front and rear end wheels; and a gear arrangement.

[0025] The electric motor is fitted to each of the wheel without any gear arrangement utilizing electric power generated by the alternator coupled with the internal combustion engine to reduce frictional losses.

[0026] Yet another aspect of the preferred embodiment of the present invention, a power take off system with a power take off controller is mounted on the hybrid agriculture vehicle wherein the power take off controller controls output characteristics and is no more dependent on the internal combustion engine and the hybrid vehicle characteristics.

[0027] As per Figure 1 of the present invention, the chassis 44 acts as a mounting base for a hybrid agriculture vehicle assembly. The internal combustion engine 15 is mounted on the chassis 44 to be operated with diesel or gasoline or compressed natural gas or any other appropriate source as the fuel for combustion.

[0028] The Chassis 44 as shown in Figure 1, is a fabricated chassis which gives flexibility to strengthen the hybrid agriculture vehicle assembly with ease and when required. The internal combustion engine 15 which is integrated over the chassis is electronically controlled 4 cylinder engine with no turbocharger.

[0029] As per Figure 2 of the present invention, one of the motor 14 from the plurality of motors is mechanically coupled to one of a rear wheel assembly 11 directly without any intermediate gear arrangement or transmission. A motor output shaft 13 is directly coupled to a wheel rim 12.

[0030] As per Figure 3 of the present invention, the internal combustion engine 15 is controlled by the engine electronic control unit 19. The engine electronic control unit 19 as shown in the Figure 3 controls the amount of fuel entering in the internal combustion engine at any point of time and in turn gets the control commands from the power management controller 20. The internal combustion engine 15 is mechanically coupled with an alternator 16, the entire engine output power is converted into electric power by the alternator 16.

[0031] The Alternator 16 as shown in Figure 3, is brushless, oil cooled with IP 68 rating which will empower it to be rugged and gives it the much needed safety parameter. The power generated is a 3 phase 400V output.

[0032] The power generated by the alternator 16 is directed to the traction motors 14, 18, 35, 36 respectively. Further, there is no power storage devices between the alternator 16 and the wheel motors. The front traction motors 14, 18 and rear traction motors 35, 36 are controlled by the torque management controllers 21, 22, 33, 34 respectively. The load requirements are sent to the power management controllers 20 which control the alternator 16 and the power generation process. The said wheel motors are oil cooled three phase induction motors.

[0033] The front traction motors 14, 18 and rear traction motors 35, 36 are the only means of operating the hybrid agriculture vehicle.

[0034] The number of traction motors used in the hybrid agriculture vehicle is two or four but the same is not limited to two or four as disclosed in the present embodiment of invention. The number of motors can be increased or reduced as per the load requirement of the hybrid agriculture vehicle. The power rating of the motors varies for e.g.: the front two motors and the rear motors have different power rating or the same power rating.

[0035] The control inputs for the torque management controllers are shared from the cabin management controller 23. The cabin management controller basically controls the other controllers including the power management controller 20.

[0036] The cabin management controller 23, controls the other controllers with the aid of the input signals from sensor positioned at various places with the intent of registering a feedback of the vehicle dynamics.

[0037] The steering system as disclosed in Figure 3 of the present invention, is empowered with a steering sensor 26 which helps in effort less turning of the hybrid agriculture vehicle. The steering sensor 26 is a force feedback motor with an incremental encoder which helps in the operation. The encoder sends the signals to the Cabin Management controller 23 on the human effort and the controller controls the steering.

[0038] The steering system incorporated in the hybrid agriculture vehicle is a non-conventional hydraulic steering. The steering system enables individual control of the wheels for operational ease.

[0039] A foot throttle sensor 27, is coupled to a foot throttle pedal, hand throttle position with the help of the attached hand throttle angle sensor 28, the break feedback are sensed by the brake pedal sensor 29. The aforementioned sensors constitute the feedback outputs based on which the cabin management controller 23 operates. An additional brake sensor for the right side shall be optional if operator requires. In that case we shall have left brake pedal sensor 29 and Right brake pedal sensor 30.

[0040] On single brake pedal operation, there will a toggle switch to switch between the left and right brake application. The brakes will be electronically controlled

[0041] All the sensors are directly connected to the Cabin Management Controller thus facilitating an error or lag free control and feedback system.

[0042] The necessary outputs and the user inputs for certain operations shall be communicated through a processing device 24. The processing device 24 acts as an user interface with graphic icons. The communication between the Cabin Management Controller 23 and the processing device 24 is through Wi-Fi.

[0043] The processing device 24 can be an android tablet or IoS or computing device.

[0044] The Cabin management controller 23 and the processing device 24 has the required provisions for the Wi-Fi communication with transducers 40 and 39 respectively.

[0045] The power take-off is a provision through which the tractor transfers the mechanical work input required by the other implements. In the present invention, the power take-off motor 32 also includes a controller namely power take-off controller 25. The Power Take-off motor 32 is an IP68 rated Oil cooled, three phase induction motor.

[0046] The power-take off controller 25 controls the output characteristics of the power take off, thus the provision is no more dependent on the engine operational characteristics and the vehicle operating conditions. The power take-off operates in variable speed range based on the operator requirement over a free range.

[0047] The hybrid vehicle of the present invention has an electro hydraulic pump 31 which is mounted near the rear end of the tractor thus shortening the hydraulic piping and the oriented hydraulic losses.

[0048] The electro hydraulic pump 31 is a constant drive gear pump. The pump is driven by a 400V electric motor delivering a constant output of required flow rate and pressure. The output of the pump is dedicated to the implement handling.

[0049] The Power Take-Off motor 32 is an optional addon. The alternate option to the system is to supply power to the implement and the implement will have a motor mounted to it. The power delivered to the implement will also be a 400V.

[0050] The vehicle provides an electric power for the implements attached to the rear via an implement power supply socket 37 positioned on the rear and front of the vehicle based on the requirement. This paves the way for the future electrification of the implements used in tandem with the tractor.

[0051] The vehicle is also capable of providing power for utility use through utility supply 38. The option is useful for domestic power requirements.

[0052] This is exactly replicated in the other wheel motor assemblies in the tractor. FIG. 4, shows a schematic arrangement of the compressed natural gas operated variant of the vehicle. The compressed natural gas is reserved in the high pressure compressed natural gas cylinders 2 which is used as the fuel for the tractor operation.

[0053] The Compressed Natural Gas variant of the vehicle four Compressed Natural Gas Cylinders 2 attached to the bottom of the chassis 44. The Filling valve 5 is mounted with a stable support bracket to the chassis 44 on the side bottom. The valve is positioned to easy access.

[0054] The cylinder arrangement is protected with an outer cover 45 from debris and hurdles which the machine will come across during the field operation and off road operations. FIG 6 shows the vehicle structure with Compressed Natural Gas cylinders 02 and the protective outer cover 45.

[0055] The detailed fuel layout for the compressed natural gas variant is shown in FIG.5, the compressed natural gas from the compressed natural gas cylinders 2 is bleed in a controlled manner through the tank valve 3 attached to each cylinder. The number of cylinders for the compressed natural gas storage is based on the requirements. A safety valve 1 is also attached to each compressed natural gas cylinder to avoid overpressure calamity.

[0056] The outflow from the cylinders are through a single outlet line which passes through a three-way fill valve 4, which also provides the way to fill the compressed natural gas cylinder. A shut-off valve 6 is positioned before the fill valve 4 to shut-off the gas flow in times of emergency.

[0057] The pressure in the supply line is monitored with a pressure sensor 5 and then reduced to the required pressure by the pressure regulator 7. The cylinder pressure of compressed natural gas ranges about 200 bar.

[0058] The compressed natural gas enters the engine via the fuel injection rail 10 which is controlled by the engine electronic control unit 19. The engine electronic control unit 19 controls the amount of compressed natural gas entering by controlling the width and span of injection into the cylinder.

[0059] The motor assembly is mounted onto the chassis 44 by a shock absorber 17. The shock absorber 17 also absorbs the impact shock which the vehicle faces during the operation in an uneven train or field operation.

[0060] The hybrid agricultural vehicle of the present invention requires no transmission, no differential gears or any gears between motor wheels and no power storage device. The vehicle is operated with only electrical power.

[0061] In addition, the hybrid agricultural vehicle of the present invention reduces frictional losses, eliminates lower efficiency components and has autonomous operation.

[0062] While the present invention has been described with reference to one or more preferred aspects, which have been set forth in considerable details for the purpose of making a complete disclosure of the invention, such aspects are merely exemplary and are not intended to be limiting or represent an exhaustive enumeration of all aspects of the invention. Further, it will be apparent to those skill in the art that numerous changes may be made in such details without departing from the spirit and the principles of the invention.

CLAIMS:

1. A hybrid agriculture vehicle, comprising:

   - a chassis (44) acting as a mounting base;
   - an internal combustion engine (15), mounted on the chassis (44) controlled by an engine electronic control unit (19);
   - an alternator (16), mechanically coupled with the internal combustion engine (15);
   - a plurality of front and rear traction motors; controlled by a plurality of torque management controllers, respectively;
   - a plurality of front wheels and rear end wheels;
   - a gear arrangement; and
   - a power take off system with a power take off controller (25);

   wherein, each of the traction motor is fitted to each of the wheel without any gear arrangement utilizing electric power generated by the alternator (16) coupled with the internal combustion engine (15) to reduce frictional losses,

   the power take off controller (25) controls output characteristics is no more dependent on the internal combustion engine and the hybrid vehicle characteristics.

2. The hybrid agriculture vehicle as claimed in claim 1 wherein, the engine electronic unit (19) controls the amount of fuel entering in the internal combustion engine (15).

3. The hybrid agriculture vehicle as claimed in claim 1 wherein, power generated by the alternator (16) is directed to the plurality of front traction motors and rear traction motors without any power storage.

4. The hybrid agriculture vehicle as claimed in claim 1 wherein, the plurality of front traction motors and rear traction motors are oil-cooled three-phase induction motors with IP 68 rating.

5. The hybrid agriculture vehicle as claimed in claim 1, comprising:

   - a cabin management controller (23);

- a hydraulic steering system;
- a power management controller (20);
- a plurality of sensors;
- a processing device (24) with a wi-fi module; and a plurality of transducers.

6. The hybrid agriculture vehicle as claimed in claim 1 and 5 wherein, the cabin management controller controls the power management controller and the torque management controller.

7. The hybrid agriculture vehicle as claimed in claim 1 and 5 wherein, the hydraulic steering system enables control of the plurality of wheels.

8. The hybrid agriculture vehicle as claimed in claim 1 and 5 wherein, the plurality of sensors are connected to the cabin management controller.

9. The hybrid agriculture vehicle as claimed in claim 1 and 5 wherein, the processing device is Android or IoS enabled.

10. The hybrid agricultural vehicle as claimed in claim 1 and 5 wherein, the processing device is connected to the cabin management controller.

11. The hybrid agricultural vehicle as claimed in claim 1, 5 and 10 wherein, the cabin management controller and the processing device are connected through the wi-fi module.

12. The hybrid agricultural vehicle as claimed in claim 1 and 5 wherein, the plurality of transducers are configured in the cabin management controller and the processing device, respectively.

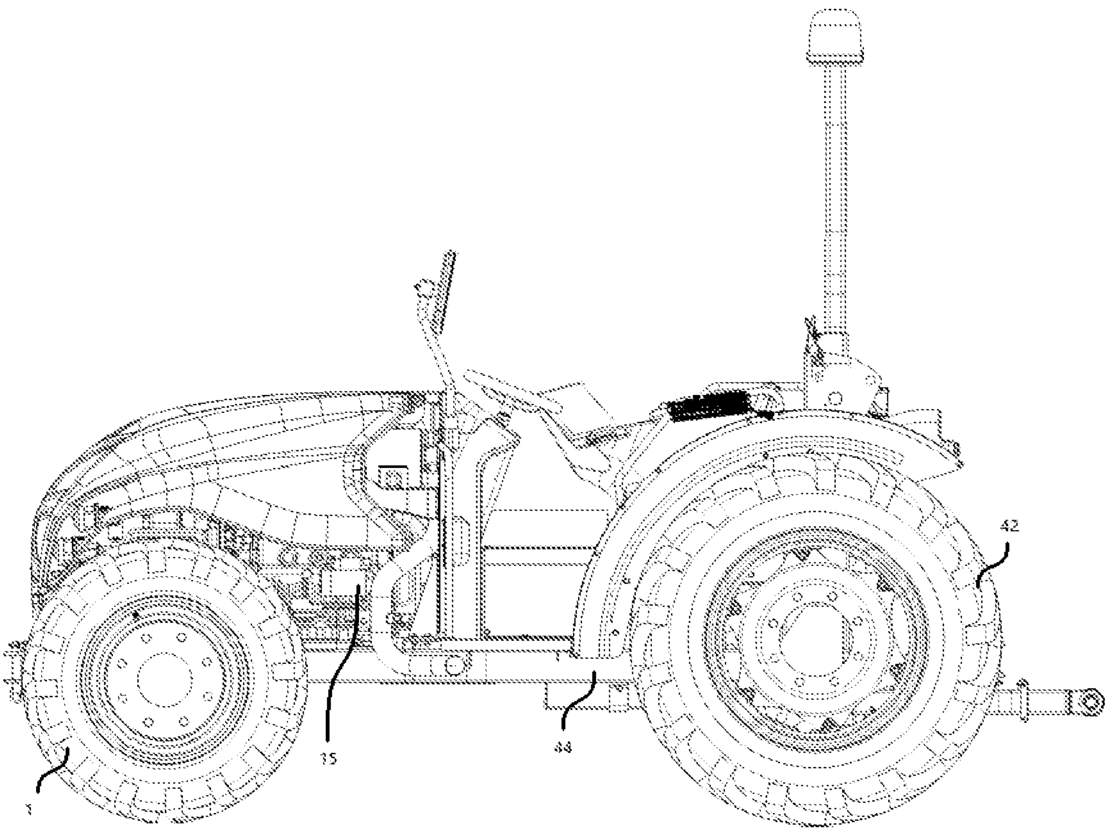

FIG. 1

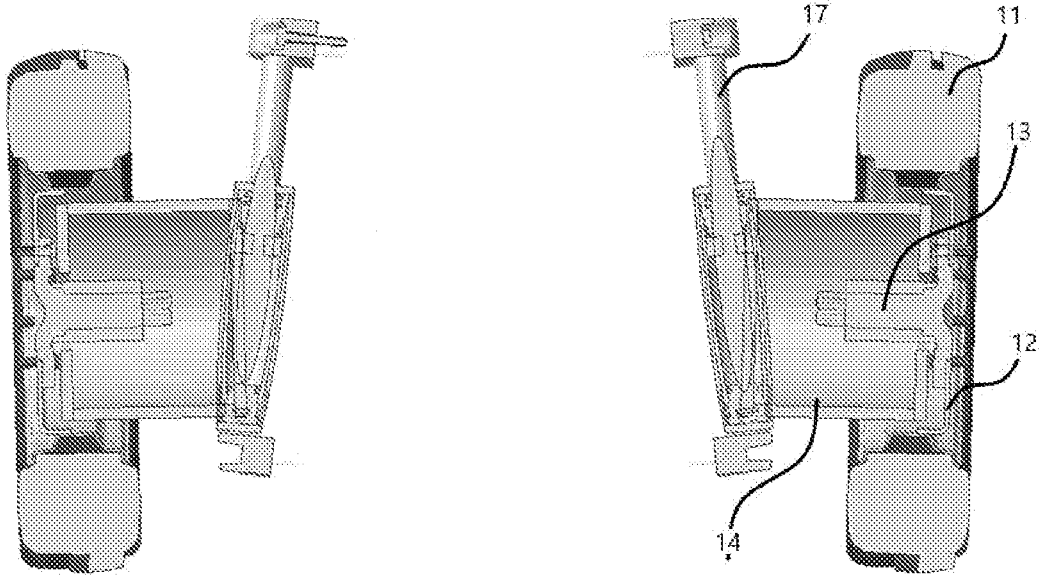

FIG. 2

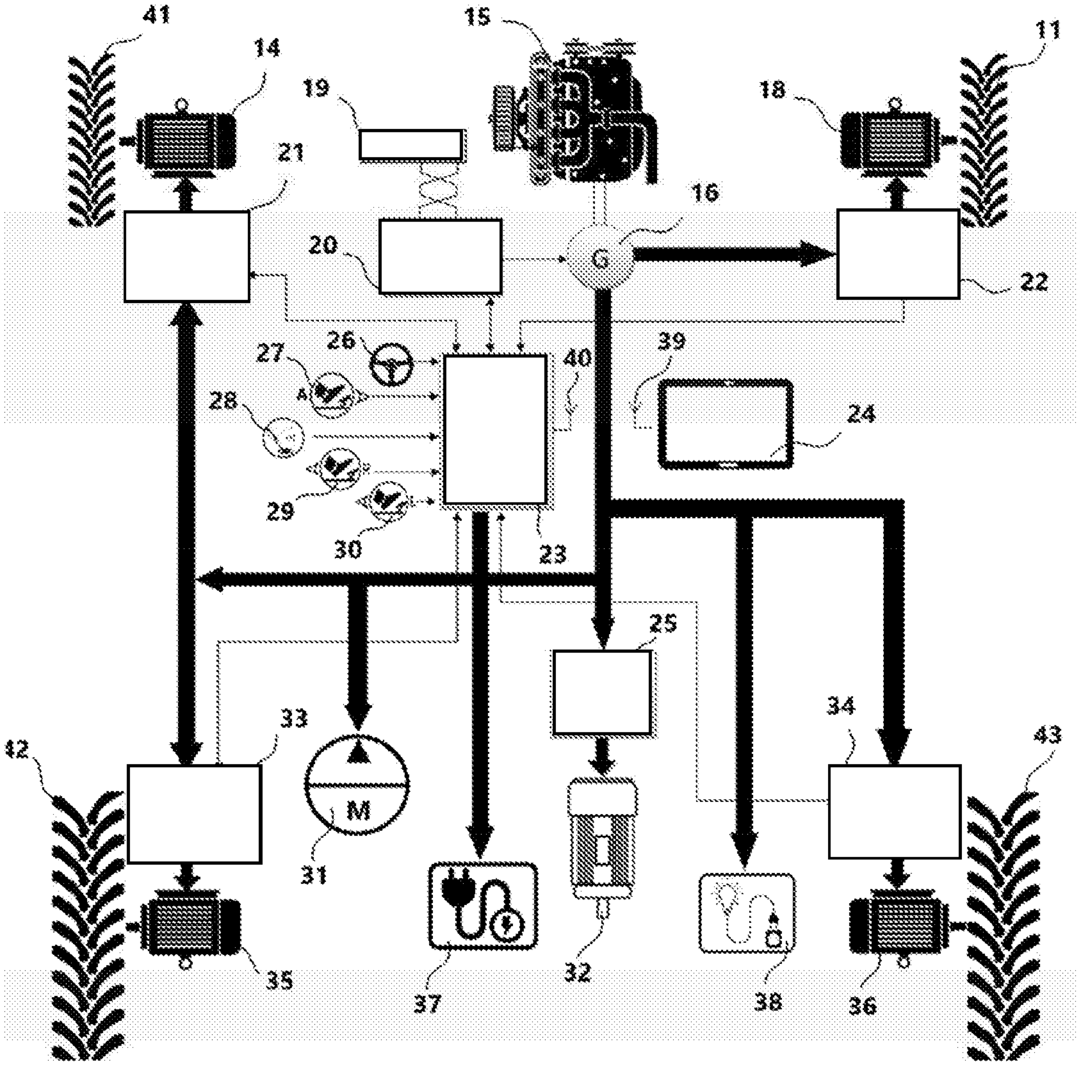
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FIG. 3

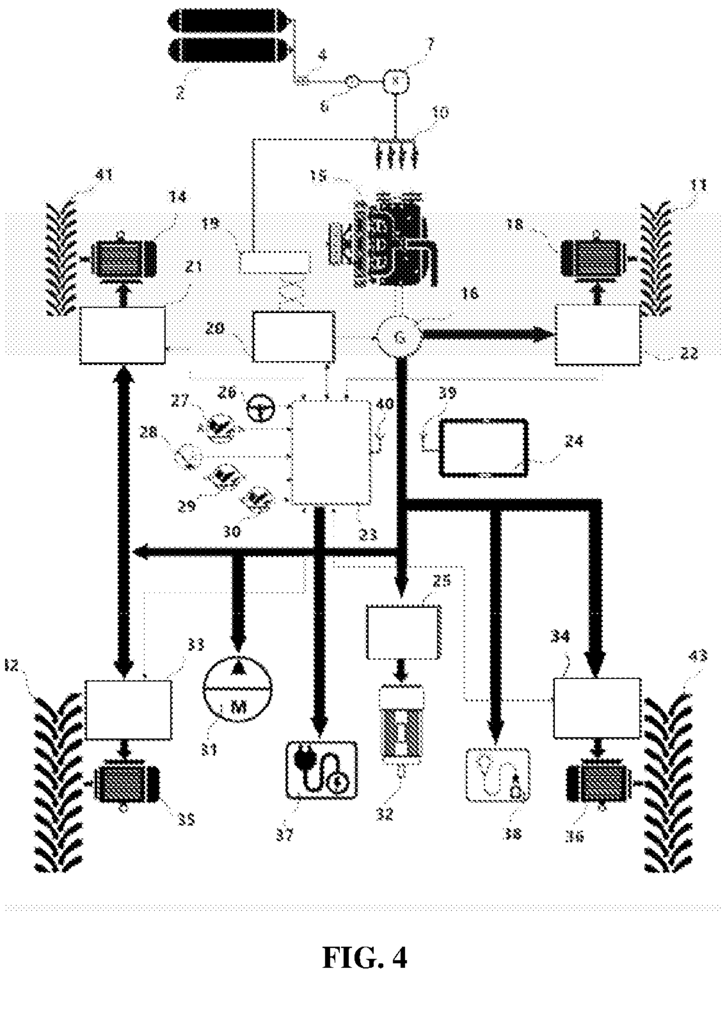

FIG. 4

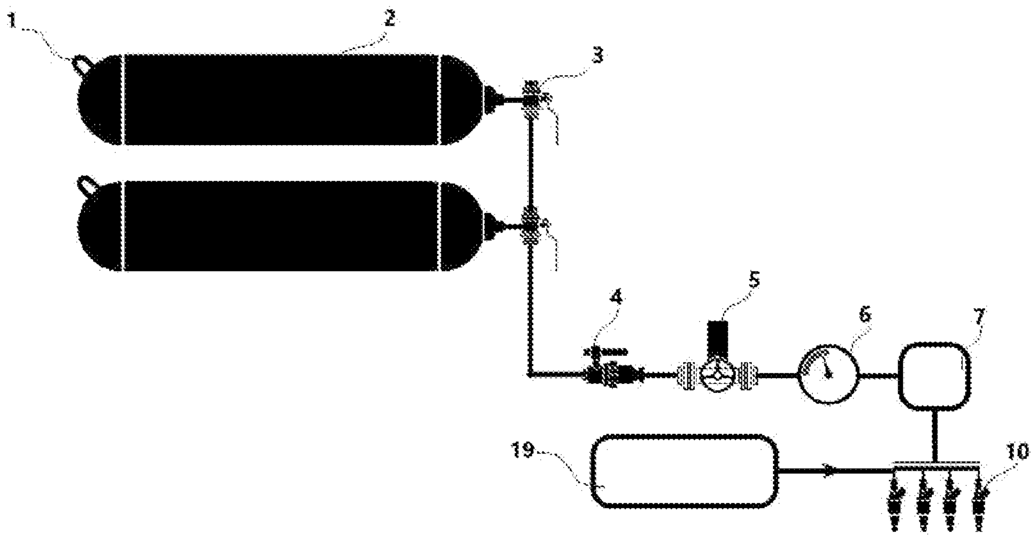

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2020/051181

A. CLASSIFICATION OF SUBJECT MATTER
B60K6/20,A01B71/06 Version=2020.01

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)

B60K

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 practicable, search terms used)

TotalPatent One, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	US 8115334 B2 (GENERAL ELECTRIC CO) 14.02.2012 (14 February, 2012) Abstract; figure 1	1-4
Y	WO 2014178599 A1 (DAEDONG IND CO LTD) 06.11.2014 (06 November, 2014) Abstract As per English translation on Espacenet; figure 2	5-12
Y	US 7142098 B2 (LANG MEKRA NORTH AMERICA LLC) 28.11.2006 (28 November, 2006) Abstract; Para [010], [012])	5-12

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13-07-2020	13-07-2020

Name and mailing address of the ISA/	Authorized officer
Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Rajiv Ranjan Sinha Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2020/051181

Citation	Pub.Date	Family	Pub.Date
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United States Patent [19]

Christianson et al.

[11] **Patent Number: 4,662,472**

[45] **Date of Patent: May 5, 1987**

[54] ELECTRIC TRACTOR

[76] Inventors: **Leslie L. Christianson,** Rte. 3, Box 118; **Ralph Alcock,** 127 Jefferson Ave. South; **Donell P. Froehlich,** 2120 Derdall Dr.; **Mylo A. Hellickson,** 2104 Olwien St., all of Brookings, S. Dak. 57006

[21] Appl. No.: **654,168**

[22] Filed: **Sep. 24, 1984**

[51] **Int. Cl.**[4] **B60K 17/30;** H02P 5/16

[52] **U.S. Cl.** **180/235;** 180/53.5; 180/65.7; 180/69.6

[58] **Field of Search** 180/235, 53.1, 53.5, 180/53.8, 69.6, 65.1, 65.6, 65.7, 65.8, 65.4

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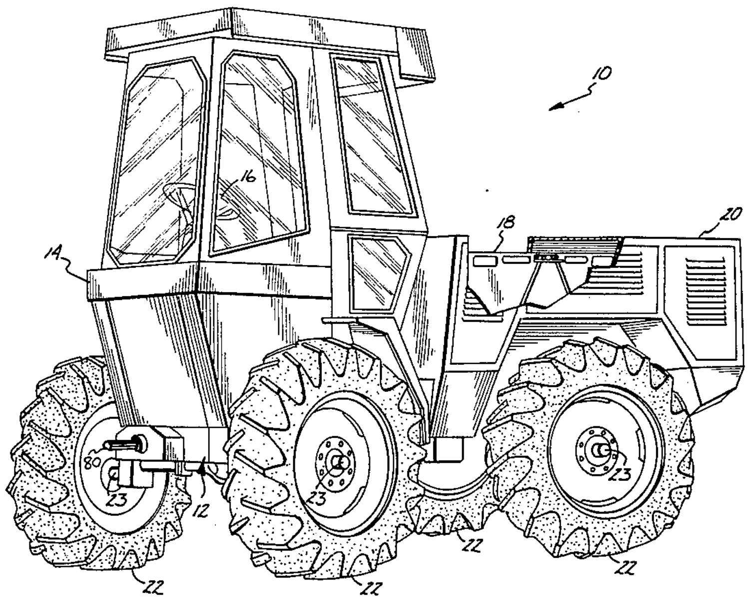
Primary Examiner—John J. Love
Assistant Examiner—Donn McGiehan
Attorney, Agent, or Firm—Kinney & Lange

[57] **ABSTRACT**

An articulated battery-powered electric tractor includes front and rear frame members which are pivotally connected for movement about a substantially vertical axis. A hydraulically-actuated articulation apparatus pivots the front and rear frame members with respect to each other. Wheels support the frame members for travel over the ground. A power-take-off shaft is mounted to the front frame member and is used for driving implements. Electric energy is stored in batteries which are mounted to the rear frame member. The first electric motor is mounted to the rear frame member and is used to drive the tractor wheels. A second electric motor is mounted to the front frame member and is used to drive the power-take-off shaft and the hydraulic articulation apparatus.

28 Claims, 5 Drawing Figures



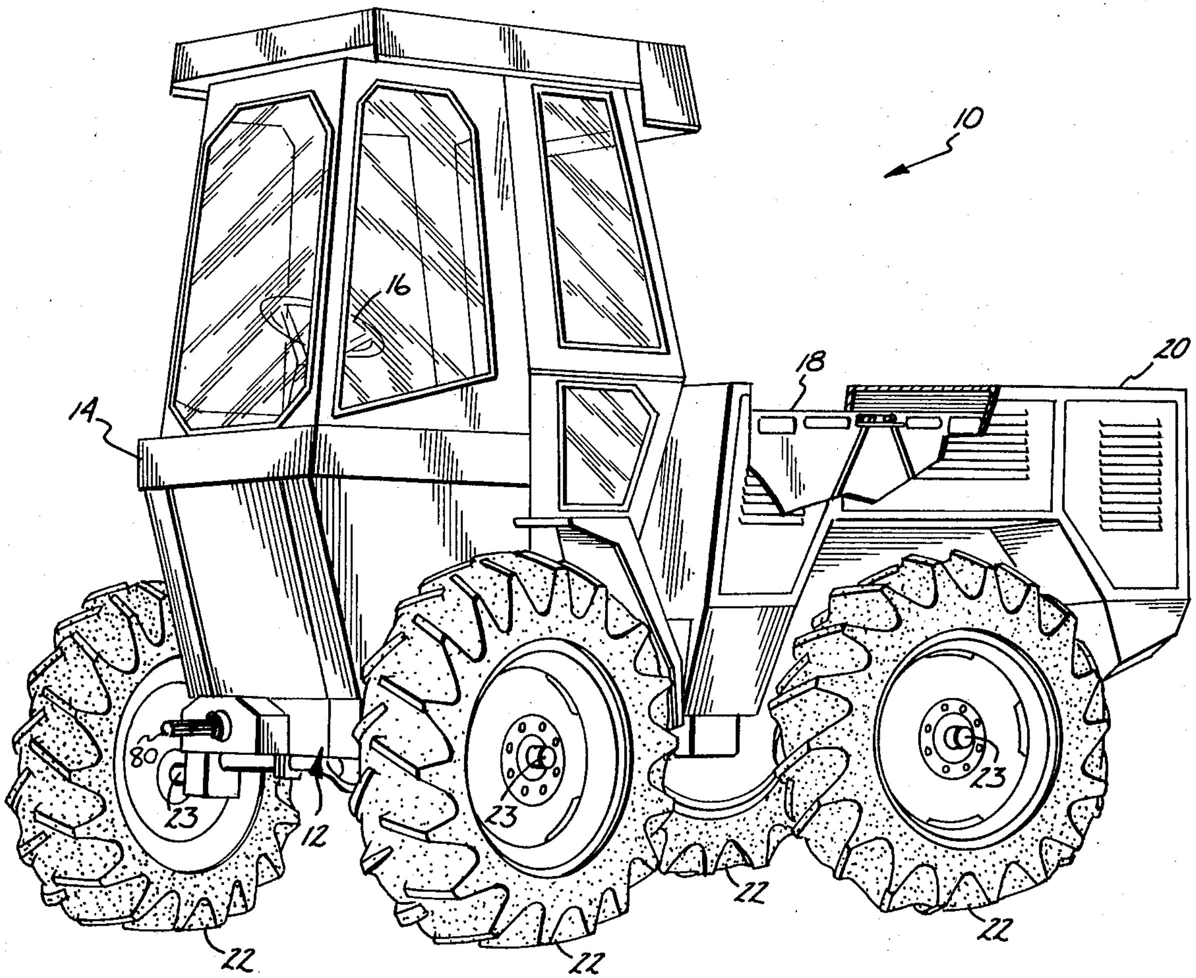


Fig. 1

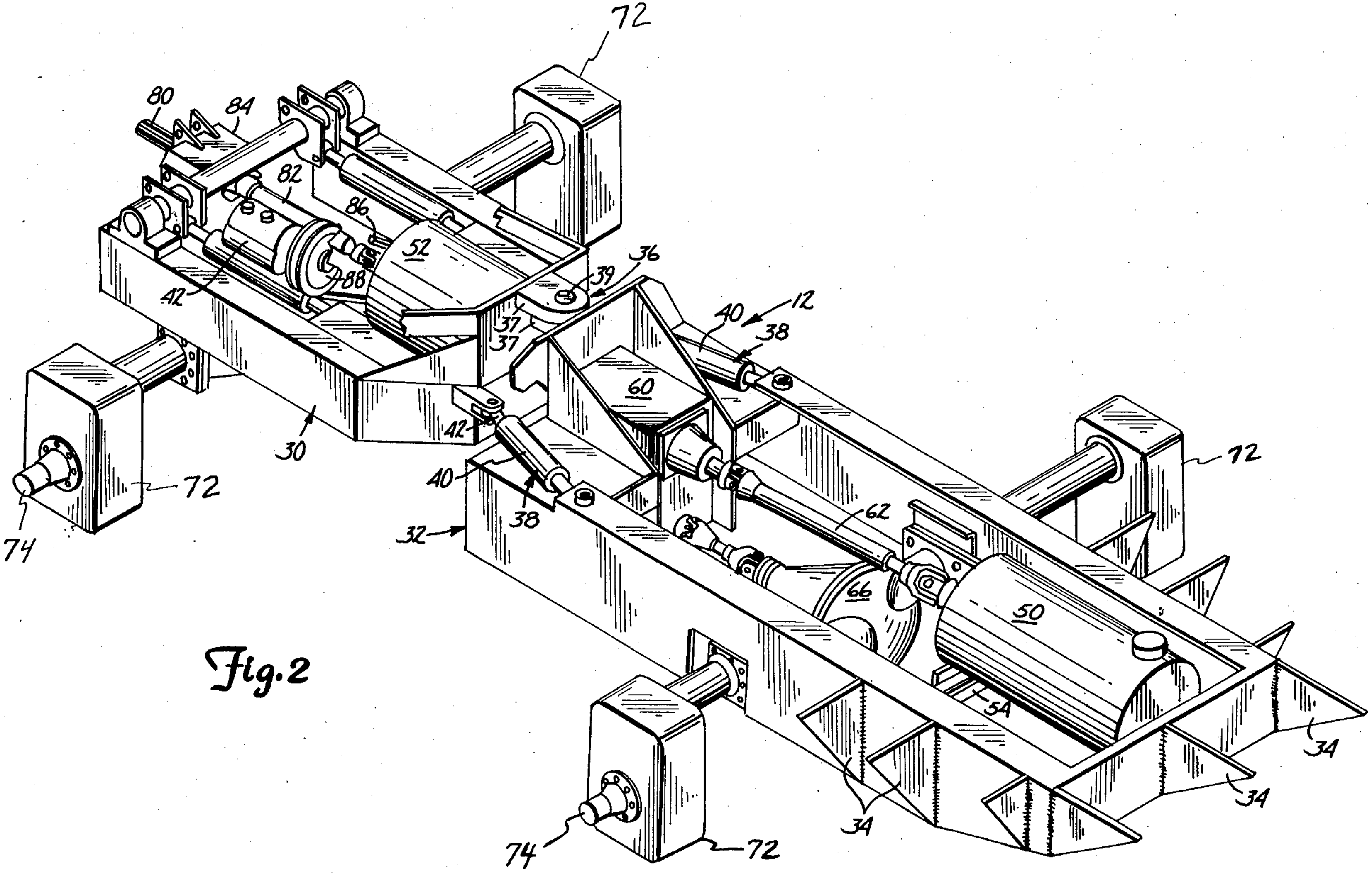

72
80
84
82
86
52
42
88
36
39
37
37
40
12
38
60
42
30
72
74
40
38
32
62
72
66
50
54
34
34
34
74
72

Fig.2

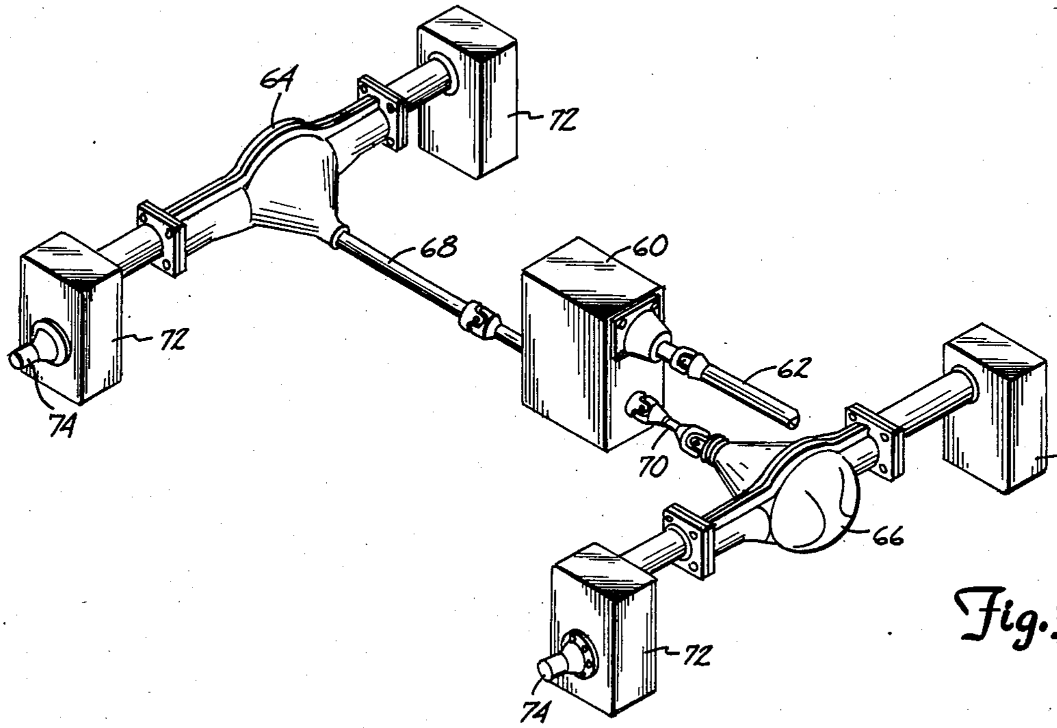

64
72
68
60
72
74
62
70
72
66
72
74

Fig. 3

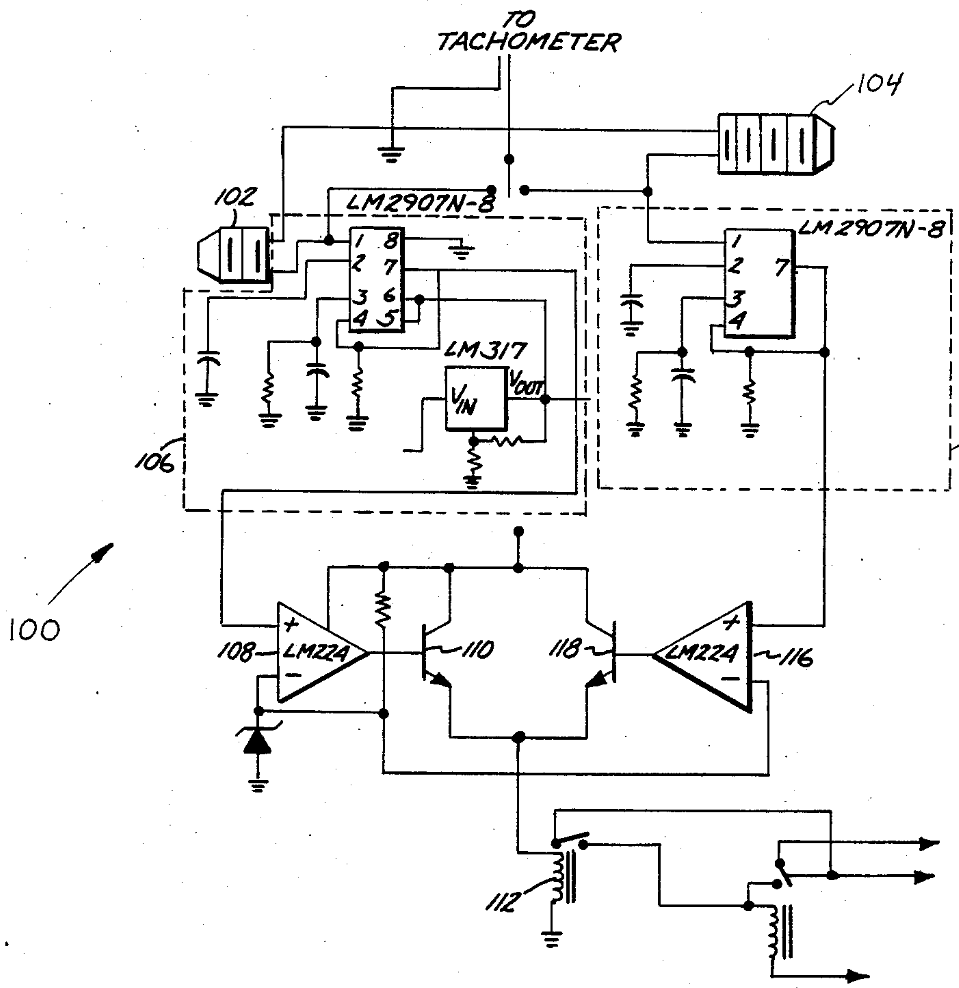
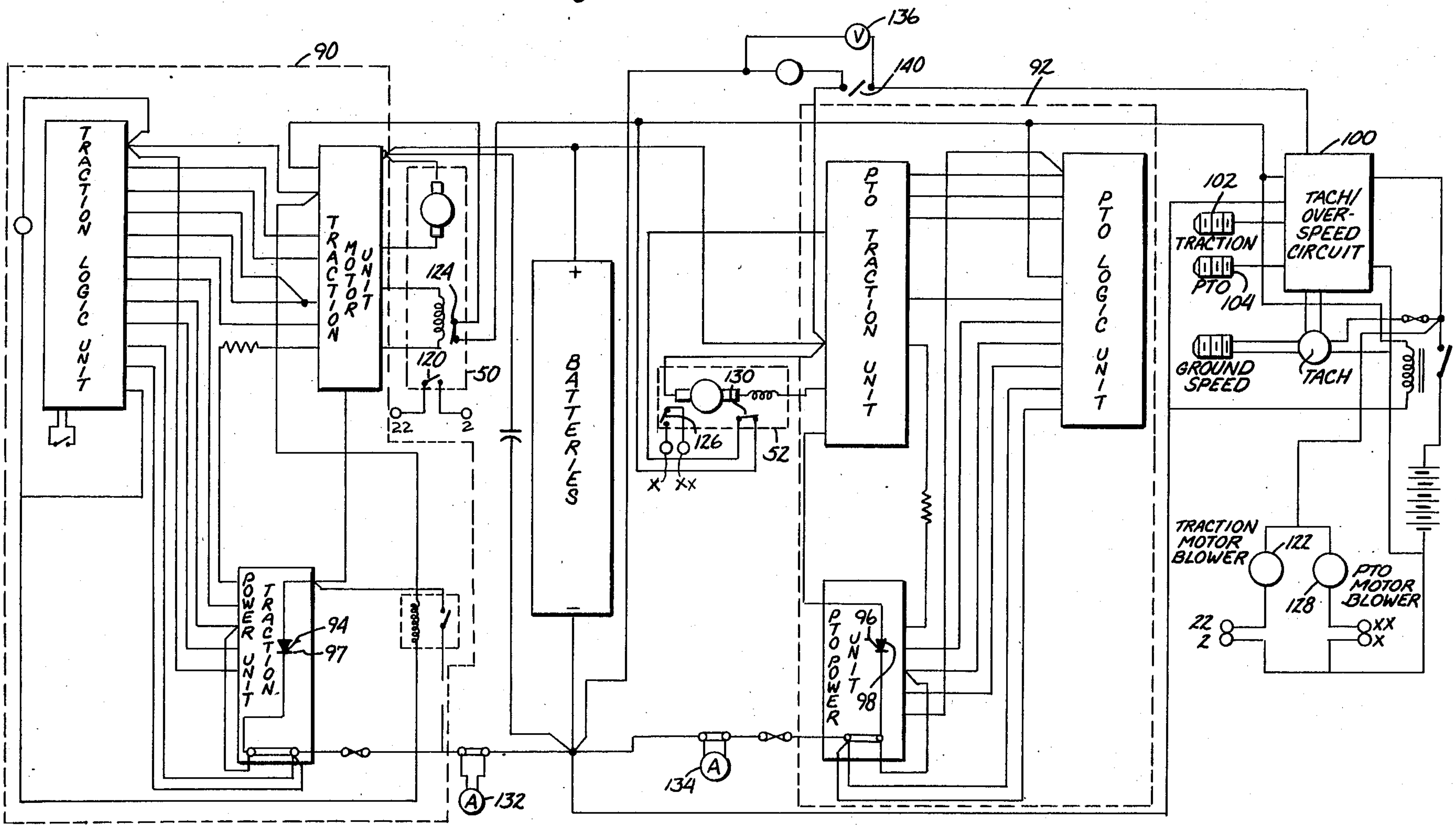

TO TACHOMETER
104
102
LM2907N-8
LM2907N-8
LM317
V_{IN}
V_{OUT}
106
114
100
108
LM224
110
118
LM224
116
112

Fig. 5

Fig.4


90
TRACTION LOGIC UNIT
TRACTION MOTOR UNIT
124
120
50
22
2
POWER UNIT TRACTION
94
97
132
A
BATTERIES
+
−
136
V
140
92
130
126
52
X
XX
134
A
PTO TRACTION UNIT
PTO LOGIC UNIT
PTO POWER UNIT
96
98
100
TACH/ OVER-SPEED CIRCUIT
102
TRACTION
PTO
104
GROUND SPEED
TACH
TRACTION MOTOR BLOWER
122
128
PTO MOTOR BLOWER
22
2
XX
X

ELECTRIC TRACTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to tractors. In particular, the present invention relates to battery-powered electric tractors.

2. Description of the Prior Art

Across the United States and throughout the world, agricultural tractors are used to plow fields, plant seed, harvest crops and perform countless other chores. Indeed, these vehicles are extremely versatile and well suited for use within the often harsh agricultural environment. Modern tractors are almost exclusively powdered by internal combustion engines which run on petroleum-based fuels. The diesel engine has in fact become the most popular power source for agricultural tractors. These engines provide acceptable power output characteristics and, until recently, fuel has been readily available, even though relatively expensive.

The characteristics of tractors powered by internal combustion engines are, however, less than ideal. Operating expenses are heavily dependent upon the price of fuels. Gasoline and diesel fuel prices have been rising sharply in recent years, greatly increasing the operating expenses. Extensive use within harsh environments often results in mechanical failures. Internal combustion engines on tractors also require a great deal of complicated and expensive maintenance. Diesel engines are also very difficult to start during cold weather. Tractor "down time" due to these factors can be very expensive for a farmer, especially when they occur during critical time periods.

It is undesirable to use tractors driven by internal combustion engines for many farmyard tasks. Extensive work within enclosed buildings is often required. Hazards posed by exhaust fumes severely restrict the use of tractors powered by internal combustion engines for these applications. Livestock are easily disturbed by the noise of internal combustion engines. It is, therefore, undesirable to use tractors of this type for chores performed in close proximity to livestock.

Although diesel engines do provide some degree of torque "back up" with reduced engine speed, their power output characteristics are less than ideal. Another problem is that the power-take-off (PTO) which is used to drive implements attached to a tractor is typically driven by the main tractor engine. Even though the PTO may be driven through a separate transmission, its operating speed is a function of tractor engine speed. This can result in undesired limitations on the speed at which an operator can run the implements.

Potential uses for an electric battery-powered tractor are becoming more evident every day. A study by Resen et al entitled "Electric Vehicles—Assessment of Potential as it Relates to Farm Size," A.S.A.E. Paper NCR80-201 (1980), has suggested that up to half of all tasks on eastern South Dakota farms could be performed by a battery-powered tractor. Similar projections were made for farms throughout the United States. Current research indicates that battery-powered tractors are especially well suited for "chore-type" tasks, such as hauling, scraping, feedlot operation and the like.

In a paper entitled "State-of-the-Art Assessment of In-Use Electric and Hybrid Vehicles," DOE/TIC-10231 (1979), the Department of Energy concluded that

electric vehicles have a useful operating life far longer than vehicles with internal combustion engines. In general, electric vehicles require much less maintenance than those powered by internal combustion engines. Reduced maintenance expenses and "down time" are significant.

Electric vehicles are extremely easy to operate, quick to respond, and start with the flick of a switch. Since they do not produce toxic exhaust fumes, they may be safely used inside buildings. This feature is an important one for both the operator and livestock.

Electric tractors are much quieter than those powered by internal combustion engines. This is important in reducing hearing loss among farmers and in minimizing noise which is particularly objectionable in urban fringe areas. More signficantly, quiet operation allows a skilled operator to hear and detect equipment problems and more carefully observe livestock health.

Energy concerns are paramount with today's farmer. This fact is evidenced by intense interest in alcohol, solar, wind and other alternative energy sources. The energy vulnerability of farm operators can be greatly reduced by the adoption of electric vehicles. Electricity is inherently more versatile than oil-derived fuels and can be generated from a great variety of energy sources. Although all energy costs will likely increase over the years, it is believed that oil-derived fuel costs will increase more rapidly than electrical costs. Studies conducted by the Department of Energy have concluded that with predicted technological advances, electric vehicles will be over 50% less expensive to operate than their internal combustion counterparts by 1990.

Electric tractors will undoubtedly play an increasingly important role in agricultural applications. Their advantages are well documented. There is a continuing need for electric tractors with different power output characteristics. The electric tractor should have a power-take-off which can be operated at a wide variety of speeds independently from the drive motor. The electric tractor should be reliable and require infrequent maintenance. In addition, the tractor should be safe, clean, quiet and easy to operate.

SUMMARY OF THE INVENTION

The present invention is a battery-powered electric tractor which includes a frame upon which structural elements of the tractor are mounted. Ground-engaging means support the frame for over-the-ground travel. The tractor also includes power-take-off means mounted to the frame for driving implements. First electric motor means are mounted to the frame for driving the ground-engaging means. Second electric motor means are mounted to the frame and are used to drive a power-take-off means. Both the first and second electric motor means are supplied with electric energy from storage means.

In preferred embodiments, the frame is articulated and includes first and second frame members which are pivotally connected for movement about a substantially vertical axis. Hydraulic articulation means are used to pivot the front and rear frame members with respect to each other. The hydraulic means are driven by the first electric motor means.

In still other embodiments, the storage means include batteries and the ground-engaging means include wheels. Electric control means are used to control the flow of electric energy from the batteries to the first and second motor means in response to operator controlled transducer means. The control means vary the width and frequency of voltage pulses applied to the motor means.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of the electric tractor of the present invention.

FIG. 2 is a perspective view of the tractor frame showing the traction and PTO motors mounted thereto.

FIG. 3 is a perspective view of the drive system and transmission of the tractor.

FIG. 4 is a schematic diagram of the electric control system of the tractor.

FIG. 5 is a detailed schematic of the tach/overspeed circuit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Battery-powered electric tractor **10** of the present invention is illustrated generally in FIG. **1**. Tractor **10** is very easy to operate and requires little maintenance. Studies have shown that the vehicle is well suited for many "chore-type" tasks, including scraping, hauling and feedlot operation.

As shown in FIG. **1**, tractor **10** includes frame **12** upon which all mechanical structures of the vehicle are assembled. Positioned near a front of frame **12** is cab **14**. An operator of electric tractor **10** will be seated within cab **14**. Cab **14** will include all control apparatus required to operate the vehicle. Although not shown, this control apparatus will include a start switch, speed control levers, gear selection levers, and various instruments. Steering wheel **16** is also positioned within cab **14** and is used to steer the vehicle.

In preferred embodiments, tractor **10** is a four-wheel drive vehicle. As shown in FIG. **1**, ground-engaging wheels **22** are mounted to axles **23**. Ground-engaging wheels **22** are driven by an electric motor and drive system which will be fully described. Tractor **10** is powered by batteries **18** which are shown mounted near a rear of frame **12**. Batteries **18** are enclosed by panels **20**.

A. Frame

Frame **12** of tractor **10** is best illustrated in FIG. **2**. In a preferred embodiment, frame **12** is articulated and includes first frame member **30** and second frame member **32**. As shown, first and second frame members **30** and **32**, respectively, are generally rectangular in shape. Support gussets **34** are rigidly mounted to frame **12** and are used as supports onto which other structural elements of tractor **10** are mounted.

First and second frame members **30** and **32**, respectively, are pivotally connected together by pivot apparatus **36**. Pivot apparatus **36** includes a plurality of brackets **37** (two are shown in FIG. **2**), which are mounted to first and second frame members **30** and **32**. Pivot pin **39** interconnects brackets **37**. Pivot apparatus **36** allows first and second frame members **30** and **32**, respectively, to pivot with respect to one another about a generally vertical axis.

In preferred embodiments, hydraulic means such as hydraulic jacks **38** are used to move the first and second frame members with respect to each other about pivot apparatus **36**. As shown in FIG. **2**, each hydraulic jack **38** includes a cylinder **40** which is pivotally mounted to an outer edge of second frame member **32**. Each hydraulic jack **38** also includes piston **42** which is pivotally mounted near an outer edge of first frame member **30**. Hydraulic jacks **38** are supplied with hydraulic fluid carried within a reservoir on frame **12** (not shown). The reservoir is in turn driven by hydraulic pump **42**. The hydraulic control system is used to actuate hydraulic jacks **38** in response to motion of steering wheel **16**. Although not shown, hydraulic control systems of this type are common and well known within the art.

Although preferred embodiments of tractor **10** have been described with reference to frame **12** which is articulated, it must be understood that a conventional frame and steering mechanism may also be used. In preferred embodiments, frame **12** is comprised of an articulated frame manufactured by the Versatile Company of Canada.

B. Electric Motors

Electric tractor **10** of the present invention utilizes two independently-controlled electric motors. Traction motor **50**, as best shown in FIG. **2**, is used to drive ground-engaging wheels **22**. PTO motor **52** is used to drive a power-take-off. Through the use of two separate motors, each individually controlled, it is possible to independently vary vehicle speed and power-take-off speed. This feature significantly enhances the capabilities of electric tractor **10**.

As shown in FIG. **2**, traction motor **50** is mounted by brackets **54** to second section **32** of frame **12**. In preferred embodiments, traction motor **50** is comprised of a 50 horsepower DC series wound motor manufactured by the General Electric Company. This motor has a one hour rating of 50 HP at 1500 rpm. Operating speed range of traction motor **50** is between 930 and 2750 rpm. Although traction motor **50** can operate at speeds lower than 930 rpm, these speeds are undesirable due to large current demand. Operation at speeds in excess of 2750 rpm can result in damage to traction motor **50**. These speeds are prevented by an "overspeed" switch which will be described subsequently. Traction motor **50** can supply 37 kW for one hour and 81 kW for 3.3 minutes. Also included within traction motor **50** is a thermistor (shown in FIG.-**4**), which controls the operation of a blower for cooling the motor when a particular temperature is reached.

PTO motor **52** is preferably mounted to first secton **30** of frame **12**. In preferred embodiments, PTO motor **52** is a DC series wound 25 HP motor manufactured by the General Electric Company. This motor has a one hour rating of 17 kW. Like traction motor **50**, PTO motor **52** includes a thermistor controlled blower for cooling and overspeed protection.

C. Batteries

Electric tractor **10** is powered by industrial grade lead-acid batteries **18**. Batteries **18** are preferably installed in two units, each having 32 cells. This arrangement provides a nominal operating voltage of 128 volts. The batteries currently used have a capacity of 340 amp-hours at a six hour discharge rate. Batteries **18** are capable of powering tractor **10** for four to eight hours in a typical farm chore routine. Recent interest in electric power has been generating advances in battery technology. It is expected that batteries having characteristics far exceeding those described above will be available within the upcoming years.

The capacity and discharge energy of lead-acid batteries **18** are severely affected by low temperatures.

This can create problems for a tractor which is used in colder environments. One method utilized in the present invention to overcome the problem is to provide a layer of insulation around batteries **18**. An alternative technique might be to include a heating system within the battery compartment.

The current charge condition of batteries **18** is important information for the operator of tractor **10**. Electric tractor **10** therefore includes instrumentation within cab **14** which displays information on the current state of batteries **18**. Voltmeters register the effective voltage which is being applied to traction motor **50** and PTO motor **52**. Ammeters display instantaneous current consumption of both motors. A tachometer indicates the rotational speed of each motor. Also included is a "fuel gauge" which provides the operator with an indication of the state of charge of the batteries. The initial battery condition is used as a reference point and each watt-hour consumed is subtracted from this reference.

Batteries **18** require periodic maintenance. Specific gravity of the electrolyte within each battery cell must be measured periodically, at least once per month. In addition, the specific gravity in two pilot cells, one in each unit of the battery, is checked on a daily basis. Batteries **18** must be re-charged when their capacity has been reduced to 20% of its nominal rating. Recharging typically takes from six to eight hours, depending on the final discharg rate of the battery.

D. Transmission and Drive System

The transmission and drive system for electric tractor **10** is best illustrated in FIGS. **2** and **3**. Rotational motion is transferred from traction motor **50** to transmission **60** by first drive shaft **62**. As shown in FIG. **2**, transmission **60** is mounted to second member **32** of frame **12**. In a preferred embodiment, transmission **60** is a three-range gear box. The first gear setting has an overall ratio of 72:1, the second gear has a ratio of 36.4:1, while the third gear has a ratio of 17.67:1. Ground speed of tractor **10** within these three gears is 0–8, 0–16, and 0–24 km/hr., respectively. Gear ratio of transmission **60** is selected by the operator through controls within cab **14**.

In a preferred embodiment, electric tractor **10** is a four-wheel drive vehicle and includes first differential **64** mounted to first frame member **30** and a second differential **66** mounted to second frame member **32**. Transmission **60** drives first differential **64** and second differential **66** through second and third drive shafts **68** and **70**, respectively. First, second and third drive shafts **62**, **68** and **70**, respectively, each include at least one universal joint.

Differentials **64** and **66** transmit power through axles (not shown) to axle gear boxes **72**. Each axle gear box **72** includes axle **74** upon which ground-engaging wheels **22** are mounted. The transmission and drive system described above is identical to that manufactured by the Versatile Company and included on the Versatile **160** Tractor.

PTO motor **52** is used to drive power-take-off shaft **80** shown in FIG. **1**. As best shown in FIG. **2**, PTO motor **52** is coupled to power-take-off shaft **80** through fourth drive shaft **82** and PTO gear box **80**. Driving PTO output shaft **80** by PTO motor **52** has been found to be very advantageous. The system allows an operator to vary the speed of PTO output shaft **80** anywhere within the operating speed rage of PTO motor **52**. Output speed of PTO shaft **80** is therefore independent of traction motor **50** and vehicle speed. This feature is very convenient and useful in many applications.

Although the hydraulic system of electric tractor **10**, including pump **42**, could be driven by a third electric motor, it has been found to be both cost and power efficient to drive hydraulic pump **42** by PTO motor **52**. As shown in FIG. **2**, hydraulic pump **42** is driven from PTO motor **52** by belt **86** and pulley **88**.

E. Electric Control System

An electric control system for electric tractor **10** is illustrated in FIG. **4**. The electric control system is used to regulate the flow of electric energy from batteries **18** to both traction motor **50** and PTO motor **52**. In preferred embodiments, the electrical control system includes two controllers manufactured by the Cableform Company. Controller **90** is used to regulate the flow of electric energy from batteries **18** to traction motor **50**. Similarly, controller **92** regulates the flow of electric energy from batteries **18** to PTO motor **52**.

Controllers **90** and **92** operate in an identical manner. Each controller applies pulse width modulated (PWM) and/or frequency modulated (FM) voltage pulses to the respective motor.

To vary the speed of either motor, an operator will adjust the position of a control lever located within cab **14**. The control lever is attached to a potentiometer which supplies a voltage of zero to five volts to input logic circuitry within the controller. Circuitry within the controller converts this voltage signal to a signal of proportional frequency. This signal is further processed and applied to switching terminals **94** and **96** of silicon controlled rectifiers (SCR) **97** and **98**. When turned on, SCR **97** interconnects batteries **18** with traction motor **50**. Similarly, batteries **18** are interconnected with PTO motor **52** when SCR **98** is switched on. When SCRs **97** and **98** are turned on, the full 128 volt potential of batteries **18** is applied across traction motor **50** and PTO motor **52**, respectively. The pulse width modulated and frequency modulated signals applied to switching terminals **94** and **96** result in voltage pulses of varying duty cycle being applied to traction motor **50** and PTO motor **52**, respectively. Speed of motors **50** and **52** is thereby varied since they respond only to an average of the applied voltage.

The electric control system shown in FIG. **4** also includes a tach/overspeed circuit **100**. Traction motor speed and PTO motor speed are monitored by transducers **102** and **104**, respectively. Transducer **102** supplies an electrical signal indicative of speed of traction motor **50**. Similarly, transducer **104** supplies an electrical signal indicative of PTO motor **52**. When either the PTO or traction motor reaches its maximum operating speed, tach/overspeed circuit **100** detects this state and actuates a device such as a relay (not shown) which overrides the respective controller and disconnects batteries **18** from the motor. The principal object of tach/overspeed circuit **100** is, therefore, to provide protection for traction motor **50** and PTO motor **52**.

A preferred embodiment of tach/overspeed circuit **100** is illustrated in FIG. **5**. Traction motor speed sensor **102** provides an electrical signal indicative of traction motor rpm. Frequency-to-voltage conversion circuit **106** converts that signal into a voltage signal representative of traction motor speed. Comparator **108** compares the voltage signal produced by frequency-to-voltage conversion circuit **106** to a reference voltage indicative of maximum motor rpm. When traction motor speed reaches its maximum rpm, comparator **108** will drive transistor **110** thereby actuating a switching device, such as relay **112**. When actuated, relay **112** will cause batteries **18** to be disconnected from traction motor **50**.

Tach/overspeed circuit **100** protects PTO motor **52** from overspeed in an identical manner. PTO shaft speed sensor **104** supplies frequency-to-voltage circuit **114** with a signal indicative of the speed of PTO motor **52**. Frequency-to-voltage conversion circuit **114** supplies a voltage signal proportional to the speed of PTO motor **52** to comparator **116**. When a voltage indicating the maximum speed of PTO motor **52** is reached, comparator **16** will drive transistor **118** thereby actuating relay **112**. In this way, electrical energy from batteries **18** is disconnected from PTO motor **52**. As previously described, traction motor **50** includes thermostatic switch **120** which will close when traction motor **50** reaches a predetermined temperature. Upon the closure of the switch **120**, traction motor blower **122** will be actuated to assist in cooling the motor. In the event a second and higher predetermined temperature is reached, thermostatically controlled switch **124** will open and cause batteries **18** to be disconnected from the motor. A similar thermostatic control system is included within PTO motor **52**. Thermally controlled switch **126** will close when the first predetermined temperature is reached. This will actuate PTO motor blower **128**. Likewise, thermostatic switch **130** will open when the second predetermined temperature is reached. PTO motor **52** is thereby disabled.

An amount of current being drawn by traction motor **50** is monitored by ammeter **132** which is mounted within cab **14**. Similarly, the current drawn by PTO motor **52** is monitored by ammeter **134**. A voltage of batteries **18** is monitored within cab **14** by voltmeter **136**. Switch **140** is actuated by an operator and initiates the application of electric energy to traction motor **50** and PTO motor **52**.

To summarize, the present invention is an electric tractor which is clean and efficient to operate. The tractor is especially well suited for performing "chore-type" tasks on a farm.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.

What is claimed is:

1. A battery-powered electric tractor comprising:

a frame;

ground-engaging wheel means for supporting the frame for over-the-ground travel;

storage battery means for storing electric energy;

power-take-off means mounted on the frame for driving implements;

first dedicated electric motor means mounted on the frame for driving only the ground-engaging wheel means and supplied with electric energy from the storage battery means;

mechanical linkage means for transferring motion from the first electric motor means to the ground-engaging wheel means, the mechanical linkage means including transmission means for selecting one of a plurality of ratios between rotational speeds of the first motor means and the ground-engaging wheel means;

second dedicated electric motor means mounted on the frame for driving only the power-take-off means and supplied with electric energy from the storage battery means;

first electric control means for controlling the flow of electric energy from the storage means to the first motor means in response to operator controlled first transducer means; and

overspeed means for preventing the flow of electric energy from the storage means to the motor means when the motor speed reaches an overspeed limit.

2. The tractor of claim **1** wherein the ground-engaging wheel means include four wheels, each wheel being driven by the first electric motor means.

3. The tractor of claim **1** wherein the frame is an articulated frame including a front and a rear frame member pivotally connected for movement about a substantially vertical axis.

4. The tractor of claim **3** and including articulation means for pivoting the front and rear frame members with respect to each other.

5. The tractor of claim **4** wherein the articulation means includes at least one hydraulic cylinder.

6. The tractor of claim **5** and including a hydraulic pump which is driven by the second electric motor means.

7. The tractor of claim **3** wherein the first electric motor means is mounted to the rear frame member.

8. The tractor of claim **7** wherein the second electric motor means is mounted to the front frame member.

9. The tractor of claim **7** wherein the power-take-off means is mounted to the front frame member.

10. The tractor of claim **9** wherein the storage battery means are mounted to the rear frame member.

11. The tractor of claim **9** wherein the power-take-off means includes a rotating shaft.

12. The tractor of claim **1** and including gear means for transferring rotational motion from the second motor means to the power-take-off means.

13. The tractor of claim **1** wherein the control means varies speed of the first motor means by varying a frequency of voltage pulses applied to the first motor means.

14. The tractor of claim **13** wherein the control means varies width of the voltage pulses applied to the first motor means.

15. The tractor of claim **1** wherein the overspeed means includes:

sensor means for providing an electric signal proportional to speed of the first motor means;

circuit means for comparing the electric signal to a reference voltage indicative of the overspeed limit and for providing an overspeed signal when speed of the first motor means reaches the overspeed limit; and

relay means responsive to the circuit means for disconnecting the storage battery means from the first motor means when the overspeed signal is detected.

16. The tractor of claim **1** and including second electric control means for controlling the flow of electric energy from the storage battery means to the second motor means in response to operator controlled second transducer means.

17. The tractor of claim **16** wherein the control means varies speed of the second motor means by varying a frequency of voltage pulses applied to the second motor means.

18. The tractor of claim 17 wherein the control means varies width of the voltage pulses applied to the second motor means.

19. The tractor of claim 16 and including overspeed means for preventing the flow of electric energy from the storage battery means to the second motor means when speed of the second motor means reaches an overspeed limit.

20. The tractor of claim 19 wherein the overspeed means includes:

sensor means for providing an electric signal proportional to speed of the second motor means;

circuit means for comparing the electric signal to a reference voltage indicative of the overspeed limit and for providing an overspeed signal when speed of the second motor means reaches the overspeed limit; and

relay means responsive to the circuit means for disconnecting the storage battery means from the second motor means when the overspeed signal is detected.

21. The tractor of claim 1 wherein the first and second motor means are DC, series wound motors.

22. An articulated battery-powered electric vehicle comprising:

front and rear members pivotally connected for movement about a substantially vertical axis;

a plurality of wheel means for supporting the frame members for travel over the ground;

articulation means for pivoting the front and rear frame members with respect to each other;

power-take-off means mounted to one of the front and rear frame members for driving implements;

storage battery means mounted to one of the front and rear frame members for storing electric energy;

first dedicated electric motor means mounted to one of the front and rear frame members for driving only the wheel means and supplied with electric energy from the storage batter means;

second dedicated electric motor means mounted to one of the front and rear frame members for driving only the power-take-off means and supplied with electric energy from the storage battery means;

mechanical linkage means for transferring motion from the first electric motor means to the wheel means, the mechanical linkage means including transmission means for selecting one of a plurality of ratios between rotational speeds of the first motor means and the wheel means;

first electric control means for controlling the flow of electric energy from the storage means to the first motor means in response to operator controlled first transducer means; and

overspeed means for preventing the flow of electric energy from the storage means to the motor means when the motor speed reaches an overspeed limit.

23. The vehicle of claim 22 wherein the articulation means is driven by the second electric motor means.

24. The vehicle of claim 23 wherein the articulation means includes hydraulic means.

25. The vehicle of claim 24 and further including hydraulic pump means for driving the hydraulic means, the hydraulic pump means being driven by the second motor means.

26. An articulated battery-powered electric vehicle comprising:

front and rear members pivotally connected for movement about a substantially vertical axis;

a plurality of wheel means for supporting the frame members for travel over the ground;

articulation means for pivoting the front and rear frame members with respect to each other;

power-take-off means mounted to one of the front and rear frame members for driving implements;

storage battery means mounted to one of the front and rear frame members for storing electric energy;

first dedicated electric motor means mounted to one of the front and rear frame members for driving only the wheel means and supplied with electric energy from the storage batter means;

second dedicated electric motor means mounted to one of the front and rear frame members for driving only the power-take-off means and supplied with electric energy from the storage battery means;

mechanical linkage means for transferring motion from the first electric motor means to the wheel means, the mechanical linkage means including transmission means for selecting one of a plurality of ratios between rotational speeds of the first motor means and the wheel means;

second electric control means for controlling the flow of electric energy from the storage means to the second motor means in response to operator controlled second transducer means; and

overspeed means for preventing the flow of electric energy from the storage means to the motor means when the motor speed reaches an overspeed limit.

27. A battery-powered electric tractor comprising:

a frame;

ground-engaging wheel means for supporting the frame for over-the-ground travel;

storage battery means for storing electric energy;

power-take-off means mounted on the frame for driving implements;

first electric motor means mounted on the frame for driving only the ground-engaging means supplied with electric energy from the storage means;

second electric motor means mounted on the frame for driving the power-take-off means supplied with electric energy from the storage means;

second electric control means for controlling the flow of electric energy from the storage means to the second motor means in response to operator controlled second transducer means; and

overspeed means for preventing the flow of electric energy from the storage means to the motor means when the motor speed reaches an overspeed limit.

28. The tractor of claim 27 wherein the overspeed means includes:

sensor means for providing an electric signal proportional to motor speed;

circuit means for comparing the electric signal to a reference voltage indicative of the overspeed limit and for providing an overspeed limit; and

relay means responsive to the circuit means for disconnecting the storage means from the motor means when the overspeed signal is detected.

* * * * *