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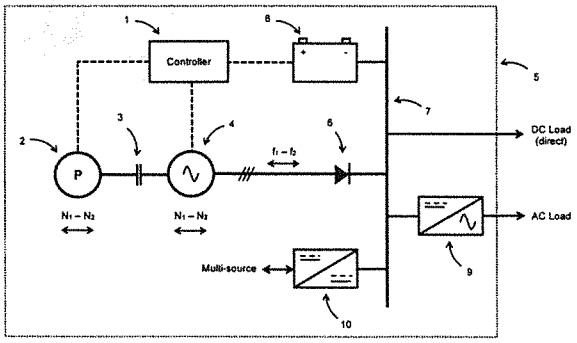
(54) **Hybrid controller and optimized electrical power system**

(57) The present invention relates to a controller device (1), which controls an electrical power system consisting of; a compression ignition diesel engine (2), directly coupled (3) to a high speed, multi pole, AC, three phrase, permanent magnet generator (4), housed in a secure environment (5), designed to operate at the engines specific, optimal, narrow speed range and at the engines optimal load in order to achieve optimal system efficient. The permanent magnet generator (4) can then be connected directly to a three phase bridge rectifier (6) which converts AC to DC and removes the constraint of fixed speed operation. A common DC bus (7) facilitates integration of energy storage, such as lithium ion technology (8), multiple source generation or supply through power converters (9,10) and feeding DC loads direct. The controller and system is optimized to produce high quality power while supporting constant current charging which is optimal for both the lithium ion battery (8) and the engine (2) and generator (4). <Figure 1>



"Hybrid controller device and optimized electrical power system"

Field of the invention:

The present invention relates to the general field of energy and electricity. In particular, it relates to optimized control and design of portable electrical power systems that can generate, store and supply electrical power in an efficient manner. The application of these power systems can be on or off grid.

International classifications:

- (H) Electricity
  - (H02) Generation, conversion, or distribution of electric power
    - (H02P) Control or regulation of electric motors, electric generators or dynamo-electric converters; controlling transformers, reactors or choke coils.
    - (H02M) Apparatus for conversion between AC and AC, between AC and DC, or between DC and DC, and for use with mains or similar power supply systems; conversion of DC or AC input power into surge output power; control or regulation thereof.
    - (H02J) Circuit arrangements or systems for supplying or distributing electric power; systems for storing electric energy.

Background to the invention:

Conventional stand alone, portable electrical generators are typically fixed speed AC systems (i.e. 50Hz / 1500rpm), connected directly to a variable electrical load. Due to their fixed speed design and lack of intelligent control, conventional generators have technical limitations such as;

- Poor ability to match variable electrical load vs. optimal fuel economy
- Overrated and oversized for the application load (due to peak load characteristics)
- A lack of integrated energy storage.

- A lack of open architecture (i.e. no ability to take in other forms of generation and storage)
- Direct coupling between the AC voltage generated and AC voltage of the load. (i.e. limited flexibility due to tight bandwidth of voltage regulation at generator output)
- Direct coupling between the AC frequency generated and AC frequency of the load. (i.e. limited flexibility due to tight bandwidth of frequency regulation at generator output)

There is a clear lack of intelligent control, optimization of subcomponents and integration of energy storage and multi-source generation in the market of portable, off grid and micro grid power systems. An ideal system achieves maximum functional value at minimum cost. This present invention aims to achieve this by maximizing operational efficiency and life cycle value at minimum operational and environmental cost, while improving reliability and reducing operational risk.
The present invention is directed towards providing such a device and system.

Summary of the Invention

According to the invention, there is a controller device, which controls an electrical power system consisting of a compression ignition diesel engine, directly coupled to a high speed, multi pole, AC, three phase, permanent magnet generator, housed in a secure, mobile, housing with environmental control.

This controller device is designed to control and operate the engine within it's specific, optimal, narrow speed range (i.e. 'sweet spot' speed range) and also to operate at the engine's optimal load rating (i.e. at or near full rated load). The high speed, multi-pole, permanent magnet generator is also selected to suit this variable speed range application. This optimized control and system design serves to maximize system operational efficiency and life cycle value at minimum operational (fuel economy) and environmental cost. Also, by utilizing direct drive, high speed, permanent magnet generators this reduces the amount of magnetic material required, limiting mass and torque loadings on the drive train and vibration, while

also eliminating the need for field excitation and voltage regulation. These features lead to a simple, reliable, robust, compact design.

In another embodiment of the invention, the permanent magnet generator is connected directly to a three phase, bridge rectifier; which converts the alternating current (AC) into high quality, direct current (DC) power. This feature serves to create a degree of freedom between the generator AC frequency and voltage and the load AC frequency voltage. Therefore, by converting to DC through simple bridge rectification, the generator and engine are no longer constrained by fixed speed / frequency, voltage (i.e. 1500rpm / 50Hz, 400V) to match the load power requirements.

The selection of multi-pole, permanent magnet generator operated at high speed through a simple bridge rectifier produces reliable, low ripple, low total harmonic distortion, high quality, DC power. This also eliminates the need for complex switching rectifier, battery charging units and extensive power filters.

In a further embodiment of the invention, the three phase bridge rectifier is connected to a common direct current (DC) bus, which creates an open architecture to facilitate integration of other sources of direct current (DC) generation (i.e. wind, hydro, solar PV) and / or energy storage (i.e. deep cycle lead acid) and / or providing power directly to appropriately rated DC loads (i.e. telecoms applications 50V DC).

DC rectification and implementation of a common DC bus allows flexible power output options offering a regulated DC 50V telecom type output or alternatively higher voltages. For example:

- Low voltage, i.e. DC Bus Voltage: 50V, suited for i.e. telecoms direct DC or AC inverter fed applications.
- Higher voltages, i.e. DC Bus Voltage: 600 – 900V, suited for AC inverter fed applications. (The higher voltage selection serves to eliminate the expense of low voltage, high current inverters in higher power applications.)

In another embodiment of the invention, a lithium ion battery (with an integrated battery management system) is connected to the common direct current (DC) bus, wherein, the controller device controls the permanent magnet generator and engine to provide constant current charging to the battery.

This creates a degree of freedom between the cycle periods of the generator and load. The engine and generator no longer require constant, continuous operation to supply the load. The battery now serves as the primary, continuous energy source to the load.

The high discharge rate capability of the lithium ion battery technology also offers an extra 'boost' supply to the load during periods high load peaks. Where a conventional generator feeding a load directly would typically be oversized and overrated to achieve these peak loads, this invention offers extra capacity from the batteries without requiring an oversized engine and generator, thus optimizing the overall package size/rating vs. load relationship.

This feature also facilitates the operation of the engine at optimal load rating (i.e. at or near full rated load) by means of constant current charging. Additionally, constant current charging (as opposed to a variable, uncontrolled charge cycle) is also optimal for lithium ion battery technology as it minimizes the stresses on the battery system. All of these features together, serve to optimize the cycle periods of the engine and to achieve optimal overall system lifetime and operational efficiency.

In another embodiment of the invention, a power converter is connected to the common DC bus, to incorporate multi-source loads, energy storage and / or generation;

This power converter can be in the form of a DC-DC converter which is used to convert the common DC bus voltage to a DC voltage appropriately rated to the match an application load and power quality requirements. This feature allows for multi-source storage and generation.

Alternatively, the power converter can be in the form of an inverter which is utilized to convert the common DC bus voltage to an AC voltage appropriately rated to the match the application load and power quality requirements.

All individual components of this system are known and proven technologies; however, the novel element of this invention is the design selection, integration and control of these sub components, together in an optimized, efficient manner.

Brief description of the drawings

The invention will be more clearly understood from the following description of an embodiment thereof, given by way of example only, with reference to the accompanying drawing in which;

- Figure 1.0 shows a general single line diagram of the system as described below.

Detailed description

Referring to drawing figure 1.0, this invention is an integrated power system which consists of the following sub components;

1. Controller
2. Compression ignition diesel engine (variable speed $N_1 - N_2$)
3. Direct mechanical coupling
4. Permanent magnet generator (high speed, multi pole, variable frequency output $f_1 - f_2$)
5. Secure, easily deployable housing with environmental control.
6. Rectifier (3 phase, bridge rectifier)
7. Common DC bus (Low voltage 50V or higher voltage 600-900V)
8. Lithium ion battery with integrated battery management system (BMS).
9. Optional AC inverter to supply AC load (fixed or variable speed/frequency, on or off grid)
10. Optional DC-DC converter to facilitate hybrid / multi-source architecture integrating other forms of energy storage or generation.

Claims:

Claim 1

A controller device, which controls an electrical power system consisting of;

a compression ignition diesel engine

directly coupled to a high speed, multi pole, alternating current, three phase, permanent magnet generator,

housed in a secure, mobile, housing with environmental control,

designed to operate at the engines specific, optimal, narrow speed range;

and operate at the engines optimal load,

in order to achieve optimal system efficiency.

Claim 2

A controller device and system, as described in claim 1, wherein;

the permanent magnet generator is connected directly to a three phase, bridge rectifier;

which converts the alternating current (AC) into high quality, direct current (DC) power.

Claim 3

A controller device and system, as described in claims 1 and 2, wherein;

the three phase bridge rectifier is connected to a common direct current (DC) bus,

which creates an open architecture to facilitate integration of other sources of direct current (DC) generation and / or energy storage and / or providing power directly to appropriately rated DC loads.

Claim 4

A controller device and system, as described in claims 1, 2 and 3, wherein;

a lithium ion battery with integrated battery management system is connected to the common direct current (DC) bus,

wherein, the controller device controls the permanent magnet generator and engine to provide constant current charging to the battery,

with optimized cycle periods to achieve optimal overall system lifetime and operational efficiency.

Claim 5

A controller device and system, as described in claims 1, 2, 3 and 4, wherein;

a power converter is connected to the common DC bus, to incorporate multi-source loads, energy storage or generation;

in one embodiment, a power converter in the form of a DC-DC converter is utilized, converting the common DC bus voltage to a DC voltage appropriately rated to the match the application load and power quality requirements.

In another embodiment, a power converter in the form of an inverter is utilized, converting the common DC bus voltage to an AC voltage appropriately rated to the match the application load and power quality requirements.

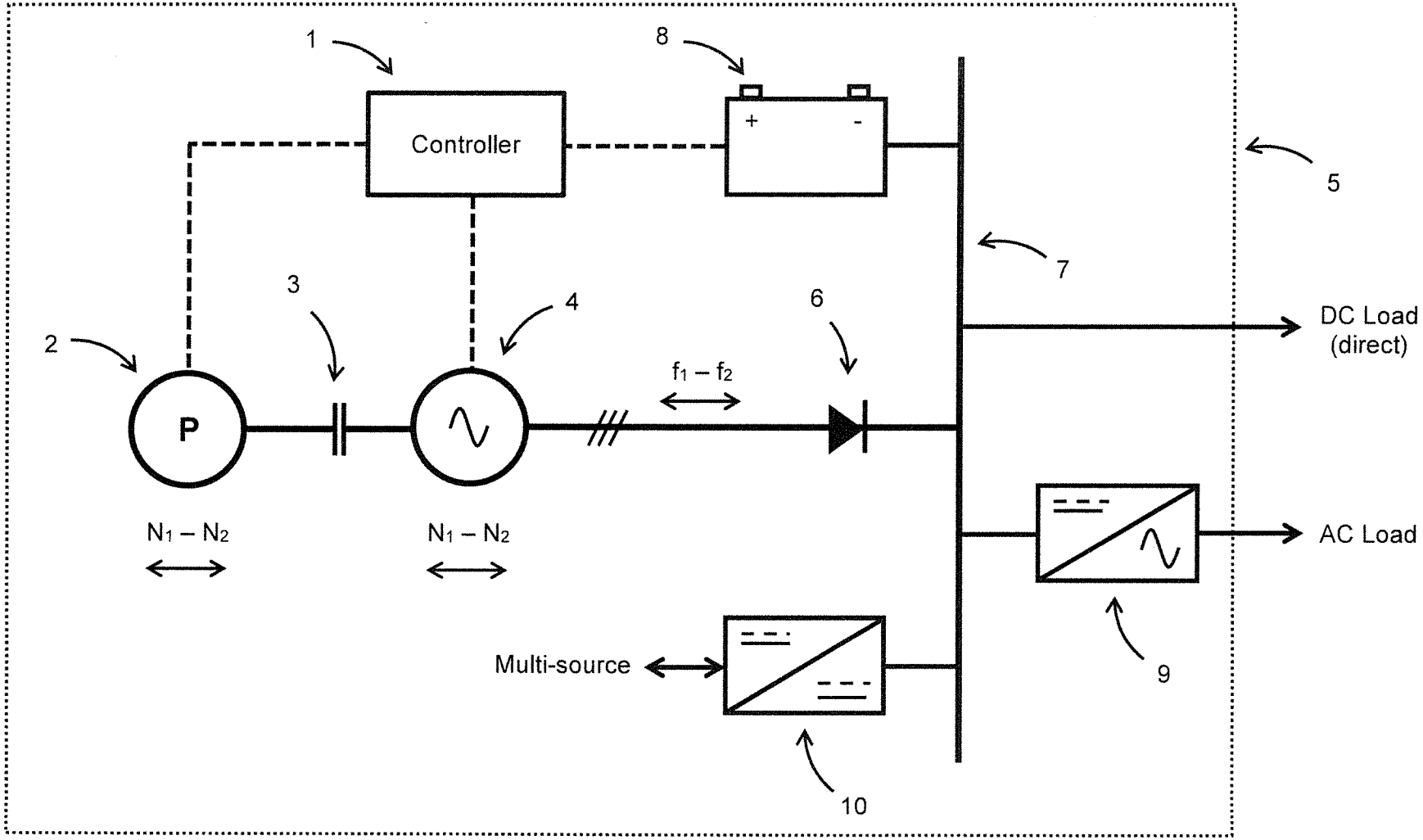

1
8
Controller
+
-
5
7
3
4
6
2
DC Load
(direct)
P
f1 – f2
N1 – N2
N1 – N2
AC Load
Multi-source
9
10

Fig. 1.0