Renewable Energy in Motor & Pump Applications

Advantages of Renewable Energy Sources

There are a number of reasons renewable energy sources are desirable to power motors, especially remote devices and water/liquid pumps. First, the cost of getting a grid connection to a remote location can be cost and time prohibitive, or in some cases just impossible. Second, renewable sources such as solar and wind need minimal maintenance or management as in the case of diesel generator power sources. And third, the ongoing cost of energy is essentially free, after the initial capital cost is amortized. Renewable sources, such as solar, can be placed in close proximity to the application which reduces transmission lengths and costs, or they can be mobile and moved from location to location as desired, all without the need of expensive electrician service calls. Solar power can easily replace noisy, costly and pollution-causing diesel generators, and with the addition of battery storage, can provide the same level of electric power 24x7.

Challenges with Renewable Energy Sources

Unlike the utility grid, or genset power sources, renewable sources are considered “non-dispatchable”. That is, the power is available only when the resource is available and not on demand. While this may be acceptable in many instances, for instance, agricultural irrigation pumping during daytime, other applications such as air conditioning or machinery may need persistent power even when the renewable source is unavailable.

Renewable sources are variable in terms of power output, with either voltage or current or both varying according to irradiance, wind speed or load size. Variations in voltage and current can cause destructive damage to the equipment being supplied and the motors will need stabilizing front ends that protect the equipment. Motors, especially brushless DC motors, benefit from a stable, or at least controllable input voltage feeding the inverter stage.

With solar power, the PV-modules are typically connected in a series string configuration and have to be matched, both electrically and orientation-wise, or the maximum energy cannot be harvested. Series string configurations are used where voltages higher than the output voltage of the PV-module are needed. But if there is mismatch, or if one of the panels is shaded or soiled, then the power output will drop to a fraction of the array’s potential. Connecting the panels in a parallel fashion mitigates some of the issues with series string at the cost of larger conductor sizes due to high currents.

Maximum energy harvesting is a prime concern, so maximum power is transferred when the source and load impedances are matched. However, solar has a highly variable maximum power point depending on irradiance and environmental conditions and provision must be made to continuously monitor and adjust the maximum power point tracking (MPPT) for optimum energy harvest. Ideally, this is performed at the PV-module, however, traditional series and parallel string connectivity prevents that and so a global MPPT, which is an average of good and bad, is performed at the load (motor).

Traditional solar installations tend to be fixed in terms of their power and energy. Once a design is complete and installed, modifying the installation to increase performance or capacity is difficult or virtually impossible without going through an expensive redesign. Ideally, only the minimum should be installed, with the ability to effortlessly increase power and energy as the demand changes.

AN ELEGANT AND COST EFFECTIVE SOLUTION

PVflex is a per module DC DC converter that has two main purposes: 1) provide maximum power transfer through local MPPT and impedance matching; and 2) convert the PV-module’s low voltage/high current to a high voltage/low current. The first point is self explanatory – maximize each PV-module’s energy harvest and output. The second point is critical because the PVflex equipped module is now an independent power generator that drives the power onto a common DC buss, regardless of the PV-module’s electrical or physical characteristics. That common DC buss can now be scaled according to needs by simply adding sources (solar, wind, battery, fuel cell, rectified generator power), limited only by the current capacity of the wiring. In turn, these wires can be increased in size to accommodate even higher power transmission.

Converting a low voltage to a high voltage allows smaller gauge wires to carry significantly more power by decreasing the current and thereby reducing I2R losses and IR

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drops. The magnitude of the buss voltage is driven by the load, ensuring that all PVflex sources provide that voltage at the load's terminals and not regulating the voltage at the source. This allows the PVflex to self-level its output voltage to compensate for any line losses and provide the load with exactly what it needs.

Having power electronics at the PV-module level has the added benefit of being able to monitor and control the output of each PV-module. Monitoring provides a way to remotely assess the health of the solar array, and gather fine resolution data on each component's performance. This information can be sent to the owner/operator for maintenance alerts, rather than relying on a scheduled maintenance cycle. Power output control can be used to either curtail power when batteries are full and loads are light, or to enable/disable the array for maintenance or safety.

Turning solar power to "always-on" power

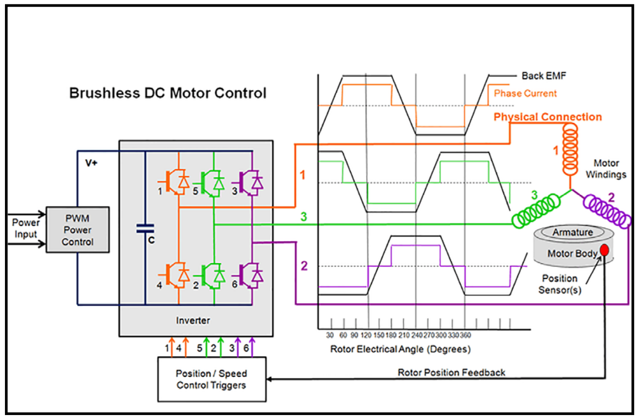
BTflex is a battery pack equipped with a bidirectional DC DC converter that bridges power flow between the battery and the high voltage DC buss. Currently, there are two configurations 4kW and 8kW power with either 6 or 12 kWh of energy storage. Similar to the PVflex, the DC DC converter matches the battery pack to the HVDC buss and its bidirectional power flow capability provides battery charge or discharge functions. The BTflex is fully self contained with its own Battery Management System (BMS) and communications link. Units can be easily added to the buss at anytime to provide as much energy storage as desired.

BTflex is battery chemistry agnostic and batteries can be chosen for their fitness for a given application. Lithium Ion - LFP, LTO, and NMC, as well as lead acid – VRLA, AGM and SLA can be used. Factors such as up-front costs, cycle life, maintenance and reliability can all be considered. And, similar to PVflex, battery types can be mixed and matched.

With BTflex and PVflex, 24x7 availability of power is realized.

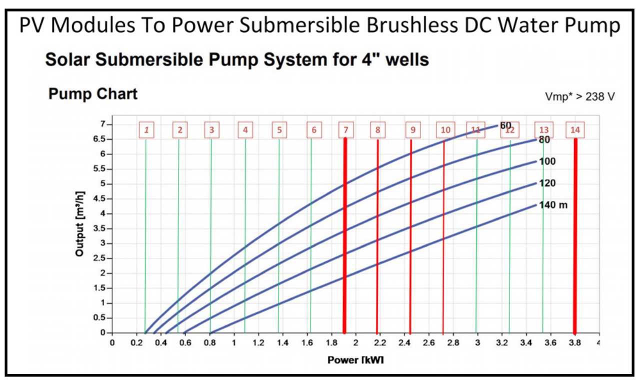
Applications in motors and water pumps

Brushless DC motors, such as those used in water pump applications, benefit from a stable or at least a controllable voltage for input into the inverter stage of the motor. Ideally, in solar applications, the motor controller should be free from tasks such as MPPT control, wide input voltage pre-regulation and regulation. Additionally, such motors benefit from a high voltage input of over 150Vdc rather than the 20-50Vdc available from PV-modules. With PVflex, the motor and pump manufacturers can design their product around an optimum voltage, rather than try to accommodate a range of possible voltages through multiple SKUs and product variations.



Brushless DC motors using back EMF for rotation sensing and control. Ideally, the voltage presented to the bridge is stable and high enough for proper motor operation. With a widely varying DC input and for MPPT control, a front end PWM controller is necessary, increasing costs and complexity.

Some motors and pumps cannot operate at lower voltages, and need to have an oversized solar array to stack the PV-module voltages to meet the operating point. PVflex optimizes the size and cost of the PV array since the voltage is already optimized from the PV-module and only enough PV-modules are needed to meet the required magnitude of current for desired head and flow rates.



Graph showing comparison of number of PV-modules to achieve desired head and flow rate. Where each PV-module is equipped with a PVflex, then only the number of PV-modules shown is needed for a given head. However, for a series string, then a minimum of 7 PV-modules (red lines) are needed. However, more than 10 cannot be in series or the pump voltage will be exceeded. For example, for a head of 80m and a flow rate of 3m3/h only 5 PV-modules with PVflex are needed but 7 modules of non-PVflex are required

With the high voltage buss, the motors or pumps can be

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located for their optimum operation, while the solar power source can be placed for its optimum power and energy harvest. Higher voltage and lower current reduces line losses, while permitting smaller conductors for power transmission. For instance, in an agricultural setting, the solar source can be placed where it achieves maximum sunlight with minimal effect on valuable real estate, while the pumps can then be located long distances away from such sources. Or, a single solar array can provide power for a series of pumps distributed throughout the property, which has the added benefit of a single point of maintenance for the solar power plant.

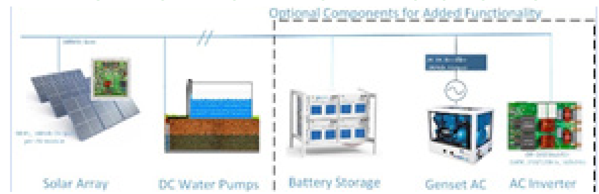
Replacement of multiple solar arrays that have one array per pump with multiple pumps and one central array and a 380Vdc Buss

Additional converters can be used to add sources other than solar to the same DC buss. This is facilitated because the power from each source is additive, with the buss being a single power collection and distribution point. Batteries, fuel cells, generators and wind can be easily added without system redesign or reconfiguration.

Persistent power can be achieved by adding battery storage to the PV source through the high voltage DC buss. Having a common DC backbone for power distribution means that sources and loads can be easily fitted to the system. The bidirectional nature of the BTflex means that the same DC buss is used for both charging and discharging of the batteries based on load and source conditions. The Pwrflex system uses a smart, autonomous agent architecture minimizing the need for site controllers or manual intervention for optimal operation.

Applications such as HVAC benefit greatly from use of Variable Frequency Drives (VFDs) that operate similarly to the brushless DC motors used in pumps. These drives can operate directly from the HVDC buss generated by solar arrays equipped with PVflex because the buss voltage is stable and the drive controllers need not regulate their inputs.

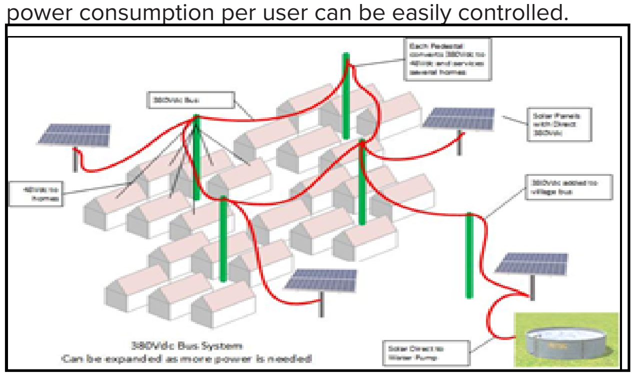
Benefits beyond powering the motor or pump



PWRflex, showing basic PV power to water pump, plus components that can be easily added to the DC buss for functionality beyond water pumping. The system is ideal for rural electrification needs and easily scales from a single residence to a community.

In emerging countries where rural populations are without electric power, but where pumps are used for water used for drinking, cooking and agriculture irrigation, the pumps are either manually operated or equipped with diesel fired generators. If a generator is used, it is invariably not used for other than its intended purpose. The use of renewable energy sources, coupled with an effective power distribution scheme, brings power not just for the motor or pump, but can also supply the entire community.

For instance, a village with irrigation needs can install a solar array to power the pump, which is used to fill a containment vessel. When the solar array is not taking the power, or even partial power, the energy can be used to power the village, with the owner collecting fees for such power. The use of a high voltage DC buss makes for a less expensive and low loss distribution from the array location to the houses in the village. This high voltage is then downconverted with step down DC DC converters for low voltage devices (LED lamps, phone chargers, tablets, TVs, internet etc.) and power consumption per user can be easily controlled.



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Demonstration System

A demonstration unit has been constructed at the company's Santa Clara design and development facility. It consists of a small PV array with each PV-module equipped with a PVflex unit that is configured for a maximum of 350Vdc buss voltage. This DC buss provides the input to a Lorentz PS4000 (7 HP, 4kW) pump and controller. The pump circulates water through a valve regulated piping return equipped with a pressure gauge. The valve simulates head and the associated pressure is displayed on the pressure gauge, which is easily converted to head. Flow rate data is provided through a Lorentz app that displays the motor's performance and flow rates.

The PV-modules can then be shaded to reduce current and demonstrate that the pump maintains pumping, although the head and flow rate are reduced proportionally. Also, PV-modules can be added or removed to show that the voltage provided to the motor is stable.

Demonstration unit with PVflex equipped solar PV-modules and brushless DC pump with external pump controller

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