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Using hybrid inverters "grid-tie mode" mode control to improve energy efficiency

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Abstract. This article analyzed the process of hybrid inverters operating in Grid-Tie Mode (grid-connected mode) and the problem of providing consumers with uninterrupted electricity during network outages. This type of inverters has anti-islanding protection, which prevents the inverter from supplying electricity to consumers in the absence of a grid or battery, by stopping the voltage at the inverter output. A pulse regulator has been proposed to help produce a 50 Hz sinusoidal product. The proposed solution is able to provide consumers uninterrupted even in battery-free mode when the solar panel generation is sufficient, effectively control energy based on the magneto-modulation direct current converter, adapt to the load requirement, and provide security protection. The results show that with the help of an improved module, the functional capabilities of hybrid inverters in an isolated state from the network are significantly expanded, increasing energy efficiency.

INTRODUCTION

As more and more people are demanding renewable sources of energy, particularly solar panels in recent years, the application of the hybrid inverters in the homes has been on the rise by the day. The strength of the hybrid inverters is that although they can be configured to operate in parallel with the power grid (Grid-tie mode), they can also be configured to operate independently as a backup power source in circumstances where the power grid is not connected. Because of this reason, there is a need to give special focus to the reaction of hybrid inverters with regards to circuit breakage and the difference in the protection mechanisms compared to the grid-tie inverters [1-3]. Typically, the grid-tie inverters are anti-islanding in operation and once the grid is off, the inverter is also off and the electrical supply being transmitted to the power consumer is terminated.because of this reason, special care is needed regarding how the hybrid inverters behave when the grid is off and the difference between their protection systems and those of grid-tie inverters. Inverters usually are Grid-tie and anti-island [4-8].

EXPERIMENTAL RESEARCH

In traditional hybrid inverters, only power grid has the ability to enable the use of the Grid-Tie Mode because the inverter is synchronized with a power grid in order to generate an output of alternating current. Most hybrid inverters are not capable of creating an alternating current output when the network fails and the battery is inaccessible because of an anti-islanding protection. Consequently, solar panels will not supply electricity to the consumers, even when they have energy, unless they have a power grid, because the inverter will adjust to the grid to generate an alternating current output. Most hybrid inverters are not capable of creating an alternating current output when the network fails and the battery is inaccessible because of an anti-islanding protection. Consequently, solar panels are not able to supply electricity to the consumers regardless of whether they have energy or not. The other extended pulse controller is also attached to the hybrid inverter in the solution suggested in this study. This module provides consumers without the magneto-modulation direct current converter of the inverter depending on the power that is available of the solar panel. This system operates in the following way in the case of the absence of network and battery. This limitation is mainly caused by the fact that a hybrid inverter will not be provided with a conventional voltage and frequency source when operating under non grid conditions, which will make it unable to sustainably regulate the phase, amplitude and frequency of the alternating current signal. The safety of the precision of anti-islanding protection is that it does not allow the inverter to provide power in such a state that it has not been connected to the grid, yet it is the case that restricts the potential of the consumer to utilize electricity [9].

Practically, most homes do not have the capacity to make use precisely the solar energy, since the capacity of solar panels available is not transferred to payloads but is sustained solely in the moat contour. Thus, the adjustment of the grid-Tie Mode mode of hybrid inverters to operate even without a network and a battery is one of the issues of technical significance. Practically, a large number of housings have the capability of being operated solely by solar power since the solar panel power accessible is not transferred to payloads, but is stored within the outline of magneto-modulation direct current converter. Thus, the adjustment of the grid-Tie Mode mode of hybrid inverters to operate even without a network and a battery is one of the issues of technical significance [10].

The enhanced Grid-Tie inverter has an additional extended pulse adjuster module. This module converts the fixed current power provided by the solar panel regardless of basic AC synchronization of the inverter, and provides a constant alternating current signal to critical loads. Consequently, the inverter can deliver power to consumers even without a network or a battery with restricted power supply. This solution extends the operational abilities of the hybrid inverter in order to raise the efficiency solar power utilization in addition to being able to guarantee continuity of electrical energy transmission amid the solar panels and load. Using the lower quoted equation we are able to calculate the constant current energy offered by the solar panels.

$$P_{SP} = U_{SP} \cdot I_{SP} \tag{1}$$

In this case, U_{SP} - Solar panel output voltage (V), V is a variable that depends on the brightness of the sun, the temperature and the load of the solar panel. A single panel is usually rated at 30-45 V (within the magneto-modulation direct current converter range, the voltage value doubles as more panels are stacked). The role of the block of magneto-modulation direct current converter is to regulate the same voltage by modulating it to the maximum power point.

I_{SP} - Solar panel output current (A), The current output of a solar panel is determined by the intensity of sunlight, the size of the panel, and the technology. In case the temperature is rising, there might be a minor increase in the panel current, a drop in the voltage. The value of the current is influenced by a sharp change in the load.

P_{SP} - Power input to the solar panel (W), This parameter shows the actual power value being inputted to the inverter or other extended pulse control module. The solar panel generation is linked to the light, as well as to the appropriate functioning of the magneto-modulation direct current converter algorithm. In case the panel voltage is leaving the range of magneto-modulation direct current converter, the power will not be optimum [11-17].

The generation of charge carriers through the photoelectric effect of sunlight energy in the solar panels is physically linked to power generation. The connection of the resulting panel is the following:

$$P_{SP} = U_{SP}(Irr, T) \cdot I_{SP}(Irr, T) \tag{2}$$

Here:

Irr - Solar radiation falling on 1 m^2 of the earth's surface (W/m^2),

T - Solar panel temperature (°C),

U_{SP} and I_{SP} vary in value depending on time, load, and temperature.

$$P_{SP} = U_{SP} \cdot I_{SP} \approx k \cdot Irr \tag{3}$$

$$k = \frac{P_{SP}}{Irr}; \quad k \approx \frac{U_{pk} \cdot I_{pk}}{Irr} \tag{4}$$

k is a coefficient that represents the ratio that relates power to current.

That is, the coefficient of proportionality of the power and current is k, which is dependent on the circumstances of working of the system or the inverter. In simple words, it is revealed how the power k is dependent on the current. Thus, it emerges to make the best of these coefficients and other parameters. Optimal working point of these parameters is then brought into play by the services of hybrid inverters through magneto-modulation direct current converter [18-20].

However when a network is not connected in Grid-Tie Mode then magneto-modulation direct current converter will not operate and the panel power will become useless - hence better extended pulse adjuster will be presented. The proposed extended pulse adjuster stabilizes it. The following is done in this module:

- Maximizes the power of the solar panel with the aid of the maximum power direct current converter magneto-modulation;
- generates a constant current voltage necessary to convert the output voltage to 220/230 V alternating current according to the consumer's requirements;
- provides protection through fast current limiting;

Constant current converter magneto-modulation direct current converter: Control:

$$\frac{dP}{dU} = 0 \quad (5)$$

depending on the condition, it has the specified voltage range. That is, although the voltage may vary a little, the amount of power remains constant. since this point-Power is the optimum value in the magneto-modulation direct current converter algorithm which attempts to locate the closest point possible to this value. In this;

$$\frac{dP}{dU} > 0 \quad (6)$$

the apparatus raises the value of a voltage

$$\frac{dP}{dU} < 0 \quad (7)$$

when the voltage change leads to the decrease in the power value. This is why we shall be forced to locate the peak power. The following table shows a graph of topping the maximum power point across a magneto modulatory constant current transducer [21,22].

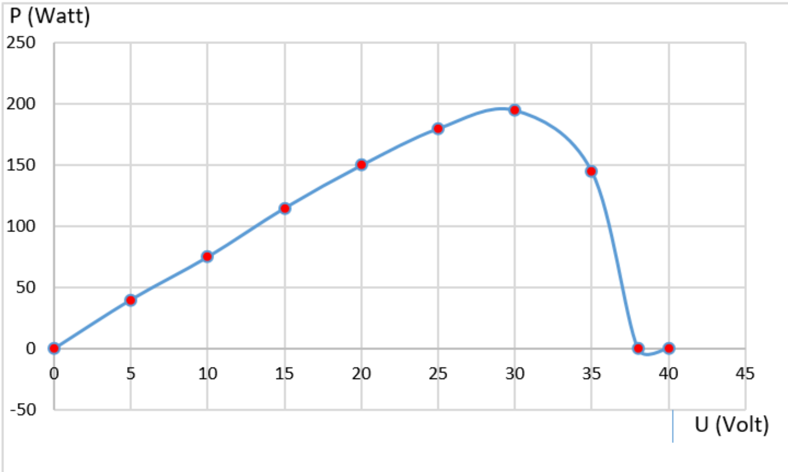

FIGURE 1. Graph of maximum power through a manitomodulation DC converter.

As a hybrid inverter do not deliver AC when there is no grid, an extra extended pulseishmover produces AC at the inverter output in anti-islanding mode by sourcing electrical energy to the inverter at a frequency of 50 Hz out of the solar panel and delivers electrical power to critical istemolians.

This module:

- does not need to sync with the network;
- The alternating current itself generates the sinusoidal shape of the signal;
- works only when the sun is available;

The general equation for sinusoidal alternating current voltage is:

$$U_{DC} = U_{pk} sin(\omega t) \quad (8)$$

In this case: U_{DC} - time-dependent alternating voltage

U_{pk} — Maximum power at the inverter output that can be achieved

ω – phase angle f – alternating current frequency

ω=2πf, f=50 Hz

RESEARCH RESULTS

The fixed current converter as proposed produces an alternative current voltage at the inverter output which is steady even in the absence of a network. This sinusoidal voltage is used as a local network of the significant chemists and varies its amplitude dynamically with the power provided by the solar panel.

This independent extended pulse controller has the following significant technical advantages:

- has a workaround on the anti-islanding constraint by simulating the external network and providing a synchronizing base to the inverter.
- the AC conversion component triggers the inverter fixed current, which means that even the energy is sent to the consumer even in the absence of the battery.
- the resulting sinuoidal has a frequency of 50 Hz Strictly, required to have normal operation of household loads.
- the device monitors the voltage amplitude and power current in real time in accordance with the load changes.

Therefore, the solution developed will remove the conventional Grid-Tie Mode constraints of a hybrid inverter enabling continuous power supply to be maintained in independent Anti-islanding mode at any rate of time so long as the solar panels are accessible. Direct supplying alternating current loads (solar panel - load) the system works on the next condition:

$$P_{SP} \geq P_{Load} \tag{9}$$

In this case; P_{SP} Solar panel power P_{Load} loading capacity.

If the solar power is less than the consumer load: the module automatically turns itself off or restricts the loading of the customers based on their importance.

The real power transmitted to the consumer in the case when the network is turned off and the battery is not available is limited by the amount of energy available in the solar panels. To mathematically represent this case, the following relation is used:

$$P_{Load}(t) = min\ (P_{SP}(t), P_{Load\_\mathrm{req}}) \tag{10}$$

Here: $P_{Load}(t)$ - The power sent to the consumer as real time. This size is an indication of the real power that is carrying the loads to the consumer loads. Its price changes over a period of time, as it would depend on the capacity of the solar panels. When the power of the solar panels goes beyond the amount necessary, the consumer becomes fully charged; failing which the limit of the load capacity will be cut short.

P_{Load_req} - The rated power required by the consumer. This value is the power that will be required to operate the devices of consumers in their normal working. It is constant with time and establishes the maximum power that is required to do the full load.

$min\ (P_{SP}(t), P_{Load\_\mathrm{req}})$ - The power of the load is limited by the power of the solar panel. This function serves to protect the load and ensure stable operation in cases where the amount of power available in solar panels is less than the consumer's demand.

If $P_{\mathrm{SP}}(\mathrm{t}) > P_{\mathrm{Load\_req}})$ loading is fully charged.

If $P_{\mathrm{SP}}(\mathrm{t}) < P_{\mathrm{Load\_req}})$ the download will only provide those if the joy of the information solar panel reaches those who wish.

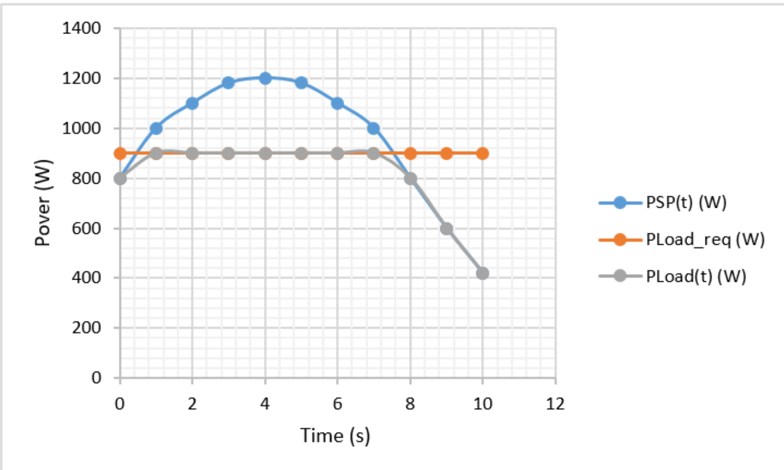

FIGURE 2. Time-dependent consumer load power.

Table 1. The table below shows the power values over time.

Time (t) (s)	P_{SP}(t) (W)	P_{Load_req} (W)	P_{Load}(t) (W)
0	800	900	800
1	1000	900	900
2	1100	900	900
3	1180	900	900
4	1200	900	900
5	1180	900	900
6	1100	900	900
7	1000	900	900
8	800	900	800
9	600	900	600
10	420	900	420

This is the real load capacity which is time-varying. If the solar panel has enough power, the charge will be at full capacity. When the power of the solar panel is low, the $P_{\text{Load}}(\text{t})$ decreases accordingly. The image above shows the optional power graph of the solar panelhis is the actual load capacity that varies in time. If the solar panel has enough power, the charge will be at full capacity. When the power of the solar panel is low, the $P_{\text{Load}}(\text{t})$ decreases accordingly. The image above shows the optional power graph of the solar panel. blue line $P_{\text{SP}}(\text{t})$ Is the real - time power of solar panels; red line(or horizontal) is the fixed power that requires $P_{\text{Load\_req}}$ loading; Green Line - $P_{\text{Load}}(t) = \min\,(P_{\text{SP}}, P_{\text{Load\_req}})$ is the actual transmitted power. The graph shows that the charge is fully charged at times when the solar panel capacity is sufficient; otherwise the istemolchi will provide electricity to consumers who have reached the capacity that the solar panel is emitting. The table below shows the power values over time.

Protection algorithm for stable system operation [23-52]. A range of protection mechanisms will be integrated in the proposed hybrid inverter-based extended pulse adjuster module, designed to provide battery-free solar panel loadings, with the aim of increasing electrical safety and reliability. These protection systems provide not only stable operation of the device, but also protection of consumers from accident situations and overload. Below is the function of the main protective blocks and their functional role in the system.

High voltage protection. The advantage of the device is that it detects when the voltage output from the solar panels exceeds the permissible limit and immediately takes protective measures to prevent damage to the inverter's AC power in the connected phases of the AC power. Such cases can be observed in the following situations:

- sudden increase in solar radiation (e.g. excessive sunlight);
- voltage surge due to excessive cooling of the solar panel;
- Increased number of serial connections due to incorrectly connected panels.

The protection system works on the basis of real–time monitoring and triggers disconnection or protection mechanisms when the voltage limit is increased. This prevents the expanded pulse adjuster elements from reaching the dielectric breakdown level.

Protection against high current. An increase in the constant current in the system from the normative value can lead to increased heat in the transistor power converter (IGBT/MOSFET) stages, melting in the wires, or failure of the semiconductor elements. For this reason, the extended pulse adjuster high current protection module performs the following functions:

- continuously monitors the current value coming from the solar panel;
- limits the control of the pulse width modulation device as the current approaches the critical limit;
- It immediately turns off the network when the current exceeds the permissible value.

This trapped protection is strong to I^2 t (Energy Integral), which limits the power to reach the heat capacity of the electrically conductive material.

Variable current short circuit protection. Since the proposed independent extended pulse adjuster operates in anti-islanding mode, all consumers can directly connect to its output. For this reason, the variable current short circuit protection system performs the following tasks:

- detects short circuits occurring on the loading side within 1-2 ms;
- ensures complete shutdown of the output amplifiers;
- The recovery function returns the system to normal mode when the danger is eliminated.

This protective inverter transformer, filters and output semiconductors eliminate damage due to excess current and ensure consumer safety.

Automatic shutdown when solar panel power is insufficient. In a battery-free solar panel supply system, the stable charging of the payload is provided only when the power that the solar panels are producing is sufficient. If:

$$P_{SP}(t) < P_{Load\_req}) \quad (11)$$

If the condition is met, the system will act as follows:

- identifies the risk of not being able to fully power the load;
- automatically turns off the extended pulse regulator to prevent a decrease in the output voltage;
- switches the system to the state of "low power standby mode" (that is, in this case, the Downloads turn off the overload depending on the need window)
- when the solar panel power is restored, $P_{\mathrm{SP}} \geq P_{\mathrm{Load}}$ will automatically restart the system.

Through the proposed extended pulse adjuster:

- even if there is no network, small power downloads (10-500 W) can work continuously;
- Maximum use of solar panel power is provided by magneto-modulation direct current converter;
- The anti-islanding constraint of the hybrid inverter is not bypassed, but provides a solution with a circular path;

CONCLUSIONS

The proposed complex of protection systems guarantees the safety, reliability and long-term operation of an independent supply model through a battery-free solar panel. High voltage, high current and short circuit protection on the alternating current and alternating current side, as well as solar panel power failure detection mechanisms maintain a safe operating mode in all functional blocks of the system. This approach expands the field of application of battery-free hybrid inverters in practice, increases their energy efficiency, and significantly improves the possibilities of operation independent of the electrical network. In cases where the network is off and the battery is not available, the grid-Tie mode of hybrid inverters usually does not work. However, by means of an additional extended pulse adjuster, providing the consumers with the electrical energy bilana through the solar panel creates a Direct Energy Transfer mechanism. This solution increases energy continuity, allows small consumers to be powered directly from the sun in real time, and reduces the negative effects of network outages.

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