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A Novel Implementation of Demand Response on Smart Grid using Renewable Energy Sources

D.Anandhavalli[1], A.R.Lalitha Ambigai[2], P.Nivethitha[3]

[1] Assistant Professor, Department of Information technology, Velammal College of Engineering and Technology, Madurai, Tamil Nadu, India. Email: dav@vcet.ac.in
[2&3]Students (Batch:2013-17) , B.Tech. Information technology, Velammal College of Engineering and Technology, Madurai, Tamil Nadu, India

Abstract- *The smart grid (SG) is a policy for modernizing the electricity transmission and distribution for a reliable and secure electricity infrastructure to meet the future demand. The demand response acts as an efficient procedure for utilities to manage system peaks by controlling customer loads. Demand automation help users to reduce their energy cost by changing their consumption patterns, shift the appliances according to their power consumption and save energy. The proposed implementation is based on grid connected dc to dc switching converter. That is usually connected between the Photovoltaic (PV) modules and the inverter. These PV converters are controlled by improved designing procedure of sliding mode controller. This drives the PV voltage to follow a reference provided by an external MPPT algorithm by considering that the switching surface which is the linear combination of the input capacitor current and the PV voltage error. The proposed design exhibits advantages in comparison with existing solutions that rely in linearization of inner current loop dynamics. The proposed power/frequency characteristics, of the hybrid unit and of the whole microgrid, adapt autonomously to the micro grid operating conditions. So the hybrid unit can supply maximum PV power, match the load, and/or charge the battery, while maintaining the power balance in the micro grid and also respecting the battery state-of-charge limits. These features which are achieved without relying on a central management system and communications, as most of the existing algorithms do. By using multi-loop controllers the control strategy is implemented, which is used to provide smooth and autonomous transitions held between the operating scenarios.*

Key Words: PV Module, MPPT Technique, PWM Generator, Circuit Breaker, Grid

1. INTRODUCTION

The smart grid (SG) is conceived as an electric grid able to deliver electricity in a controlled, smart way from points of generation to consumers. The power management strategy should consider the state-of-charge (SOC) limits and the power rating of the battery. However, unlike in standalone PV systems, in microgrids, the battery storage can be connected to the microgrid bus as a separate unit, which might be in a different location than the PV unit. Furthermore, in microgrids, the PV unit is commonly controlled.

As in grid-connected configurations, where the interfacing voltage sourced converter (VSC) is controlled as a current source to inject the available PV power into the grid/microgrid bus (the PQ control strategy).Since this technique was developed originally for grid-connected configurations, it does not address the power balance problem in islanded microgrids.

It requires access to the power measurements at each distributed generation (DG) unit and load node, through communication, in order to be able to maintain the power balance in the microgrid. This requires power measurement and communication modules at every generation and load node, which complicates the system and introduces potential failure modes. In all of the aforementioned strategies, communication is a critical part of the strategy. If the communication with any generation or load node is lost, the EMS may generate an undesirable control command. Therefore, dependence on communication for power management may reduce the reliability of the control strategy.

However, communication can still be used in the grid-connected mode as a part of the tertiary control layer to achieve certain objectives such as ensuring economic dispatch based on the electricity market and fuel prices. In this case, communications are not crucial to maintain the power balance in the microgrid, as it is achieved through the grid. Moreover the power management strategy is designed so that both the fuel cell and the battery use the droop control approach to share the peak load, when the power available from the PV unit and the micro turbine is inadequate to match the load. This might deplete the battery prematurely. Instead, it is recommended that the battery only be used during transients, and to supply the deficit power only after the load increases beyond the total capacity of the other generating units.

Photovolatic (PV) systems are a suitable option to produce clean electrical energy, since they can be dimensioned for a wide range of power ratings in both stand-alone and grid-connected applications. A typical PV system is composed by a PV array, a dc/dc converter to transform the power provided by the PV source, and an inverter. The PV array is characterized by a nonlinear behavior that changes significantly with the operating conditions, e.g., irradiance level, shades, temperature, among others, which makes difficult to predict the voltage and current to guarantee the maximum power production.

The proposed power/frequency characteristics, of the hybrid unit and of the whole microgrid, adapt autonomously to the operating conditions of the microgrid so that the hybrid unit may supply the maximum PV power, match the load, and/or charge the battery. This is accomplished while maintaining the power balance in the microgrid and respecting the battery SOC limits. In general, the battery module within the hybrid unit is controlled to offer the same operational functions that a separate storage unit can provide in an islanded microgrid, such as maintaining the microgrid power balance and regulating the voltage and frequency. Distributed generation (DG), also known as on-site generation generates electricity from many small sources such as solar, tidal, natural gas (fuel cells), wind and small hydro. Due to certain advantages like environmental friendliness (low or zero emission of pollutant gases), flexibility and expandability, DG's are considered as the best option to form modern electrical grids by properly locating them. DG technology is decentralized and is gaining increasing attention due to various advantages offered by them. The advancement in power electronics technology makes it possible to integrate DG systems to the utility.

2. PROPOSED WORK

The objective of the proposed control strategy is to coordinate the operation of the PV/battery unit with the other droop controlled units, to deliver the available PV power to the microgrid, while maintaining the power balance in the system and respecting the SOC limits and power rating of the battery. More specifically, the proposed control strategy provides the following features without relying on communications:1) The hybrid unit tracks and delivers all the available PV power to the microgrid after charging the battery to the desired SOC.2) The hybrid unit can absorb power from the microgrid to support charging the battery without disturbing the power balance in the microgrid. In other words, the power used to charge the battery will vary autonomously based on the varying load and the available power from the PV unit to ensure that the load demand is met and to avoid exceeding the power ratings of the other units.3) If the available PV power is more than the load demand, the hybrid unit will match the varying load while storing the surplus energy in the battery.4) If the battery is fully charged, or if the surplus power is higher than the battery converter rating, the control strategy will autonomously adjust the PV operating point to curtail the PV power generation so that it matches theload.5) The battery does not supply any power at steady state, unless the load increases beyond the total generation in the microgrid.

Therefore, the battery within the hybrid unit can maintain the power balance in the islanded microgrid, similar to any separate battery storage unit. The contribution of this paper is reflected in the aforementioned features, which are achieved by the proposed strategy autonomously without relying on any central management system, or on communication, as most of the existing techniques do. This improves the reliability of the system in comparison to the strategies that employ communication and central management algorithms.

3. SYSTEM ANALYSIS

It presents the comparative analysis between constant duty cycles and perturbs and observe (p&o) algorithm for extracting the power from photovoltaic array (PVA). Because of the non linear characteristics of the PV cell, the maximum power can be extracted under particular voltage condition. Therefore, maximum power point tracking (MPPT) algorithm are used in PVA to maximize the output power in order to improve the efficiency of solar panel, the MPPT is used.

The output power of any circuit can be maximized by adjusting source impedance equal to load impedance. This method addresses the deficiency in P&O algorithm under variable irradiance conditions. In order to reach at MPP this method uses the slop of differential voltage dV and current dI. The relationship of IC algorithm the disadvantage of P&O algorithm under rapidly changing irradiance condition is overcome by using IC algorithm. P&O oscillate at MPP, while IC can find its MPP and perturbation is clogged.

There is a disadvantage of IC as compared to P&O is its complexity level, If the speed of computation is not satisfied under varying atmospheric conditions.

4. SYSTEM IMPLEMENTATION

The system design is grid connected PV system using energy management controller with perturb and observe algorithm MPPT technique to provide steady state operation and increase efficiency. The system implementation is done using the modules such as PV array, DC to DC converter, INC algorithm, PWM generator, Power grid.

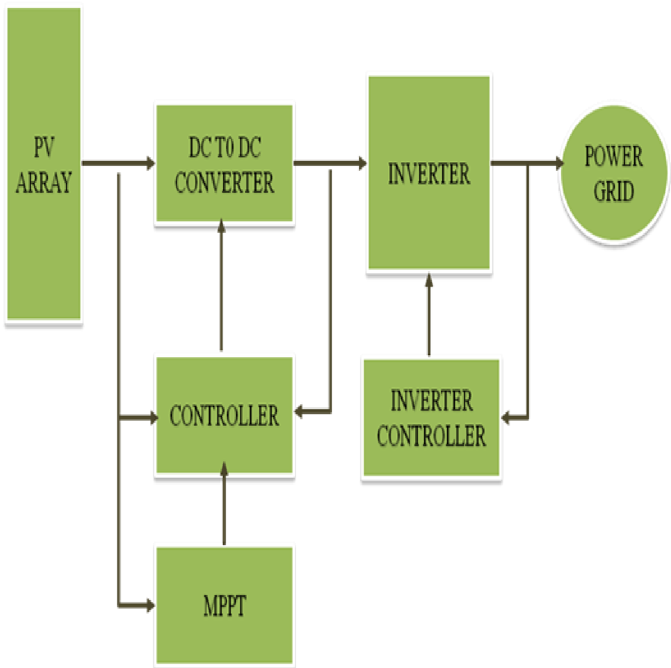

Fig -1: System Architecture

4.1. PV ARRAY

A photovoltaic system or PV system is a power system designed to supply usable solar power by means of photovoltaics. It consists of several solar panels arranged in order to absorb sunlight and change it into electricity, A solar inverter which is designed to change the electric current from DC to AC, as well as mounting, cabling. The systems overall performance is improved using a solar tacking system which includes an integrated battery solution.

Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels.

4.2. DC TO DC CONVERTER

A DC-to-DC converter is a switching regulator converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. The Power level range from very low (small batteries) to very high (high-voltage power transmission). DC to DC converters are used in portable electronic devices such as cellular phones and laptop computers, which are supplied from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply.

Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing. Most DC to DC converter circuits also regulate the output voltage.

4.3. INC Algorithm

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that “physically moves” the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different.

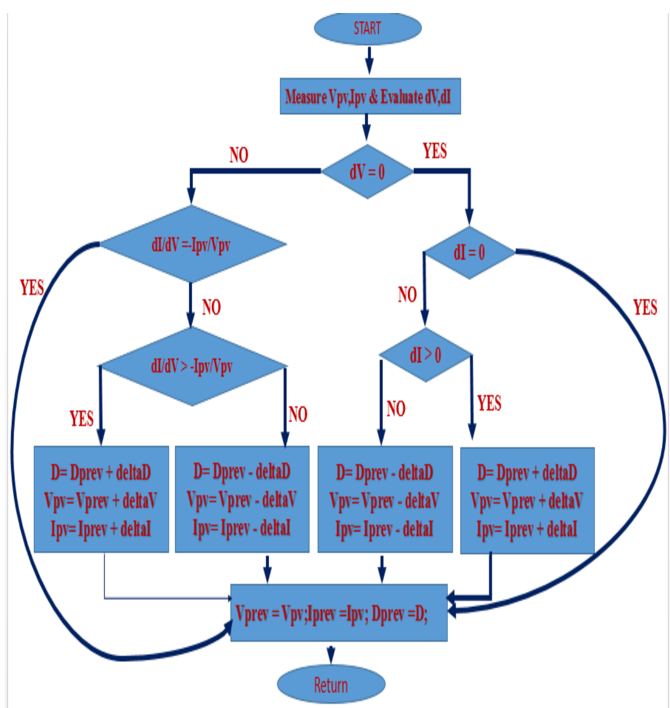

Chart -1: Flow chart of proposed system

MPPT is an essential technique that tracks the maximum power point of photovoltaic panel. Since, conventional MPPT algorithm uses a fixed step to get the optimal value of the duty cycle, many drawbacks occur. Thus, the purpose of this presented work is to suggest an improved MPPT technique which enhances the choice of the variable step size of the duty cycle and therefore improves the performances of photovoltaic system. Indeed, the concept of this new algorithm is to compute the variable step according to the slope value of Power-Voltage characteristic for photovoltaic panel.

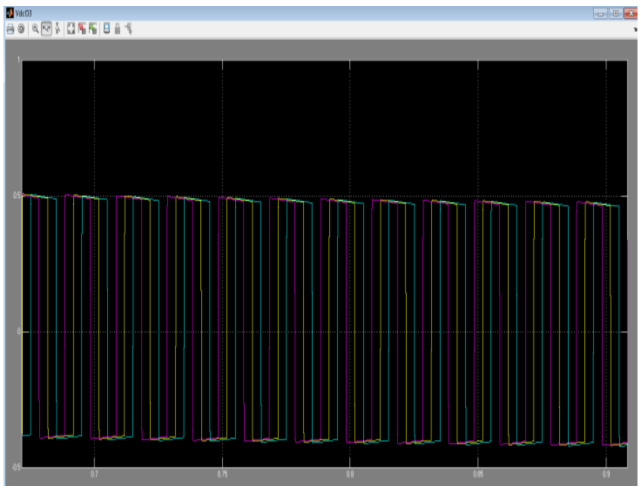

Fig-2: Inverter Output Voltage Waveform

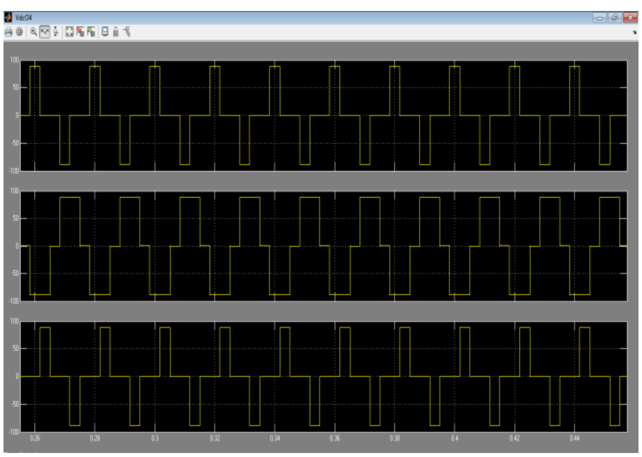

Fig-3: Phase to Phase Voltage Waveform

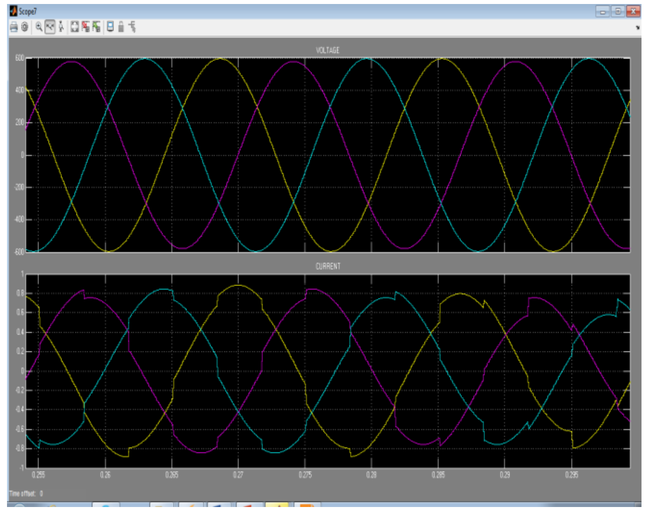

Fig-4: Grid Output Waveform

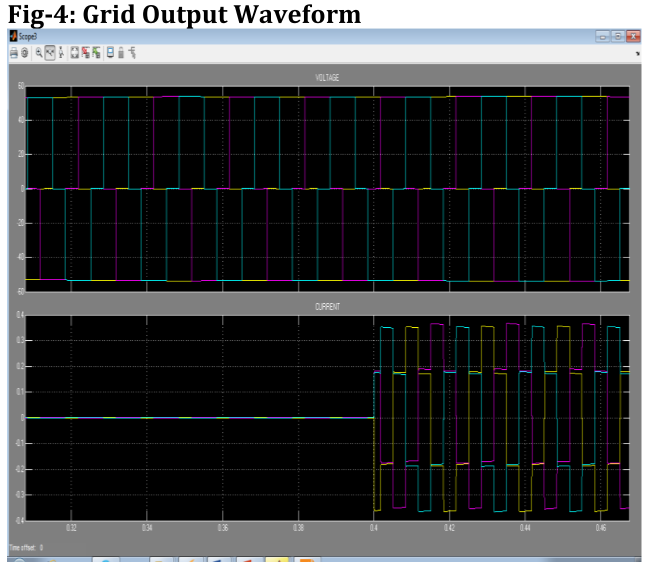

Fig-5: Load-1 Output Waveform

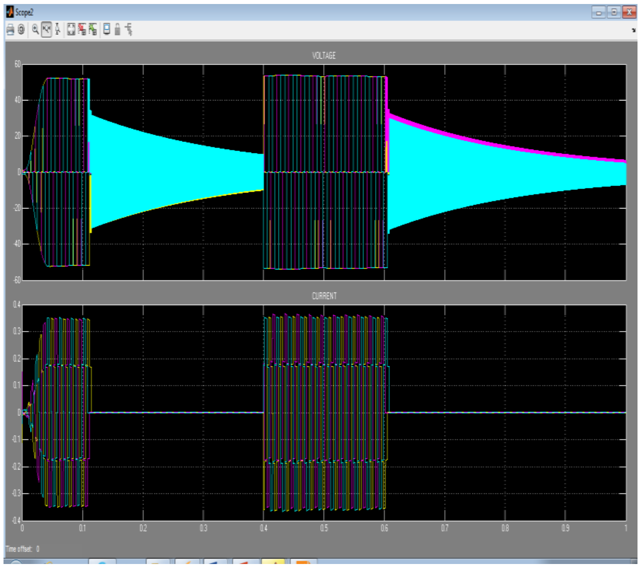

Fig-6: Load-2 Output Waveform

5. FUTURE ENCHANCEMENT

In future this design will implemented as grid connected PV based inverter using sliding mode controller with improved incremental conductance algorithm and also increase the efficiency and voltage regulation.

6. CONCLUSION

The proposed implementation is based on the SVPWM of a boost converter in a grid-connected PV system. Its PV voltage tracked the reference provided by an external MPPT with a specified settling time and no overshoot while being insensitive to changes in environmental conditions, in the analysis of the selected switching surface, formed by a linear combination of the input capacitor current and the PV voltage error, a single control loop has been considered. That used cascade controllers based on inner fast current control loops and outer voltage loops designed after a linearization of the current loop dynamic response.

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