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DESIGNING OF GRID CONNECTED INVERTER FOR PV SYSTEM

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Abstract – *In recent years, photovoltaic (PV) systems are acquiring more popularity due to their ease of availability. The photo-voltaic system can be classified into grid-connected or standalone types based on the power generation and requirements. The grid-connected photo-voltaic system is one of the primary approaches to solar energy power conversion. the microgrid is a distributed system configuration with the generation, distribution, control, storage, and consumption connected locally, which can operate isolated or connected to other microgrids or the main grid. It contrasts with traditional centralized grids through bidirectional connection with users and autonomous local control layers. Advances in control techniques, automation, energy storage technologies, communication, and superior computing processing capabilities lead to increased efficiency and reliability of microgrids compared to traditional grids. The PV power system can provide a continuous power supply during the grid blackouts, and it can inject the excess produced power into the electrical grid during the day periods. However, grid-connected PV systems cannot continue supplying electrical power during grid blackout hours due to the islanding mode of the inverter which is an essential main feature for each grid-connected inverter to satisfy the safety issues. Therefore, the electrical power generated from the PV system during blackout hours will be lost if no storage battery is available in the PV system. The proposed PV system has been simulated by Matlab software.*

Key Words: Grid-Connected PV System, solar panel, inverter, renewable energy, MATLAB/SIMULINK,

1. INTRODUCTION

The demand for electric power is on the rise and is anticipated to increase exponentially in the future. Among main sources of energy, thermal sources such as fossil fuels contribute to the bulk amount of power generation. But these fuels are expensive due to their bulky demand around the world. Also, their reserves are limited and running short. Besides this, their combustion generates pollutants gases that affect the environment in various forms. Due to these factors, renewable sources of energy are getting attention and photovoltaic systems (PV) are also becoming more prominent during the last few decades. The photovoltaic module provides a low DC voltage with a wide range according to various operating conditions A boost converter is required to step up this low DC voltage to the required DC link voltage. The conventional boost converters cannot offer such a high voltage gain. Even in the case of extreme duty ratio, the conversion efficiency is declined due to losses. This also increases the ratings of devices like output diode and other issues such as severe electromagnetic interference and reverse recovery the connection of inverters to the grid specifically is dependent on the control scheme which is adopted by these inverters. Different control schemes have been under research for grid-connected inverters in the past decade.

1.1 PHOTOVOLTAIC SYSTEM

In general, PV electrical power generation can be divided into two categories; stand-alone PV-system and grid-connected PV-system. The first category is used in remote areas where it is too expensive to be reached by the public grid system. A big disadvantage of this system is the use of batteries for the night supply since battery energy loss is too high.

The second category is a grid-connected PV system where the generated electricity is directly used and there is no need for storage. This study investigates this category since Jordan's national public grid covers 99.8% of the populated areas in the country. Figure 1 shows the main components of the grid-connected PV system. The connection to the public grid is achieved by using proper inverters. Care must be exercised to choose inverter units with the highest efficiency. During the daytime, the solar generator provides power for the electrical equipment and excess energy is supplied to the public grid. In addition, during the nighttime, the load gets its electricity from the public grid.

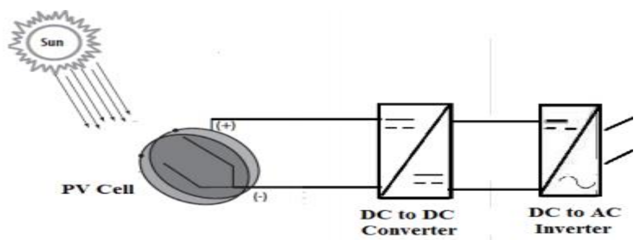


Fig -1: Grid-connected PV system

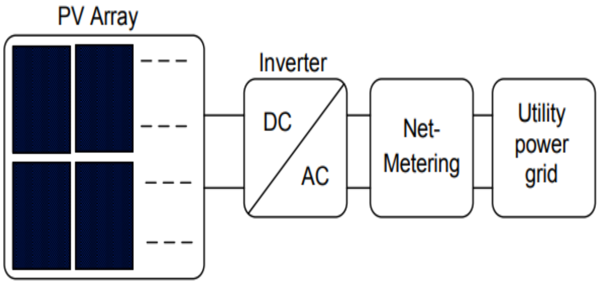


Fig -2: Grid-connected PV system

Grid-connected PV-system can be installed in different establishments where the range of power needs can be in the magnitude of watts to magnitudes of megawatts. This can be achieved by installing enough PV generators for different establishments.

1.2 Photovoltaic characteristics

The voltage and Current outputs of the PV modules are affected by temperature and irradiance [5]. Power electronics components of a photovoltaic system, such as grid-direct inverters have maximum and minimum voltage inputs. A PV module's voltage output is a variable value that is primarily affected by temperature. The relationship between module voltage and temperature is an inverse one. the module's temperature increases, the voltage value decreases, and vice versa. It is important to put into consideration the cold and hot temperatures during PV design as shown in PV calculations. If the temperature of the module is less than the STC value of 25°C, the module's open-circuited voltage, Voc value will be greater than the value listed on the module's listing label.

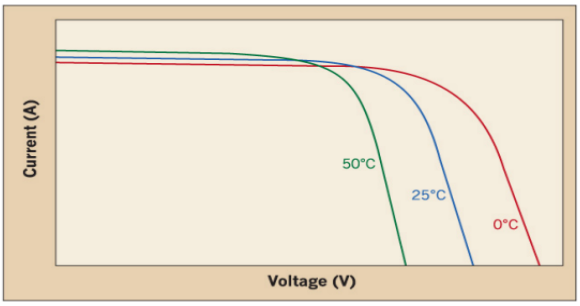


Fig -3: Current and Voltage characteristics of a PV module with temperature variation

2. Topologies of Grid Connected PV systems

Based on the photovoltaic array's output voltage, output power level, and applications, the photovoltaic grid-connected system can adopt different topologies. These configurations describe the evolution of grid-connected inverters from past, present, and future technologies. There are different technologies and topologies available for grid-connected PV systems which are categorized based on the number of power stages. In PV plant applications, various technological concepts are used for connecting the PV array to the utility grid. Each technology has its advantage and or disadvantages compared to other, interns of efficiency and maximum power point tracking. Each PV array is formed by the PV modules operating under similar environmental conditions to reduce the current limitation on the strings. In addition, the dc power is improved by a modified power processing architecture which shares out the maximum DC power extraction task among as many power processors as independent PV arrays. Depending on the number of PV arrays; string inverters, module inverters, and multi-string inverters are commonly available technologies of power processing architectures topologies supporting this strategy.

2.1 DC- DC converter topologies

The dc-dc converters mean the input is dc and the output is also dc. The two basic dc-dc converters are buck converter and boost converter. Based on these two converters, all other converters are derived. The semiconductor devices are used as switching devices due to which the converters can operate at high frequencies. The different arrangement of inductors and capacitors in the converters operates as a filter circuit. The resistance act as a load in the circuit which can be varied to study the behavior during light load and heavy load. The different types of input dc sources are used like battery, renewable energy sources, etc.

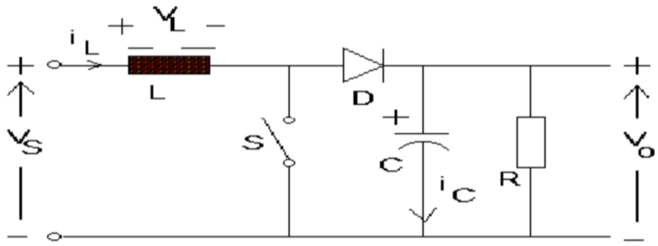


Fig -4: Basic Dc-Dc Converter Topology

The converter is operated at different frequency levels to improve the response of the converters. Normally, the converters are designed in the medium frequency range. The various types of converter are buck converter, boost converter, inverting and non-inverting buck-boost converter, Cuk-converter, SEPIC converter, full-bridge, and half-bridge converter, forward converter, push-pull converter, flyback converter, resonant converter, converter, and so on. These converters can be classified based on various categories. These converters can be classified as isolated and nonisolated converters, unidirectional and bidirectional converters, step-up and step-down converters, single-input and multi-input converters, Low power applications, and high-power application converters, etc.

Table -1: Frequency ranges

Designation	Abbreviation	Frequency Range
Extremely Low Frequency	ELF	3-30Hz
Super Low Frequency	SLF	30-300Hz
Ultra Low Frequency	ULF	300-3000Hz
Very Low Frequency	VLF	3-30KHz
Low Frequency	LF	30-300KHz
Medium Frequency	MF	300KHz-3MHz
High Frequency	HF	3-30MHz
Very High Frequency	VHF	30-300MHz
Ultra High Frequency	UHF	300MHz-3GHz
Super High Frequency	SHF	3-30GHz
Extremely High Frequency	EHF	30-300GHz

2.2 DC- AC converter topologies

An inverter is usually a device that converts DC power into AC power. In many industrial applications, it is often required to vary the output voltage of the inverter due to the following reasons:

1. To compensate for the variations in input voltage.

2. To compensates for the regulation of inverters.

3. To supply some special loads which need a variation of voltage with frequency.

To control the output voltage we are using space vector pulse width modulation. Phase-controlled converters operate in inverter mode are called line commutated inverters. But line commutated inverters require at the output terminals an existing AC supply which is used for their commutation. This means that line commutated inverters can't function as isolated AC voltage sources or as variable frequency generators with DC power at the input. Therefore, voltage level, frequency, and waveform on the AC side of the line commutated inverters can't be changed. On the other hand, force commutated inverters provide an independent AC output voltage of adjustable voltage and adjustable frequency and have therefore much wider application. With the increase of semi conductors' technology, voltage source inverters have been extending their application in various areas. In 2-level inverter output voltage waveform is produced by using PWM with two voltage levels. This causes the output voltage and current to be sinusoidal and the THD of the voltage is better. In a 2-level inverter, the efficiency of the whole system is better at full load. This means better energy capture of the system. Better efficiency at rated power means also smaller heat sink and better reliability. The efficiency of the 2-level inverter at small power is also improved.

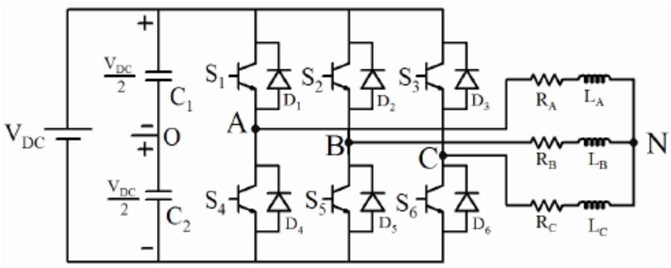


Fig -4: Basic Dc-Ac Converter Topology

2.3 Grid connected filter topologies

To supply the grid with a sinusoidal line current without harmonic distortion, the inverter is connected to the supply network via the filter. The filter is an important part of every semiconductor converter. The filter reduces the effects caused by switching semiconductor devices on other devices parameters like efficiency, weight, and volume have to be considered when choosing an optimal filter topology. Regarding efficiency, filter topologies with reduced losses are required, though those are relatively small when compared to losses in the inverter. The weight and volume of filters are considered critical due to difficulties with inverter transportation, installation, and maintenance. The filter cost depends basically on the number of components and materials used, for example, the magnetic material for the core of inductors. In addition, the filter shall be able to perform its task within a certain degree of independence of the grid parameters, like resonance susceptibility and dynamic performance are of major importance. The filters include L-filter, L-C filter, and L-C-L filter as shown in Fig. Advantages and disadvantages are pointed out based on the most important features for designing and performance of filters. Harmonic attenuation, better decoupling between filter and grid impedance, and system dynamics of these types of filters are among the performance features.

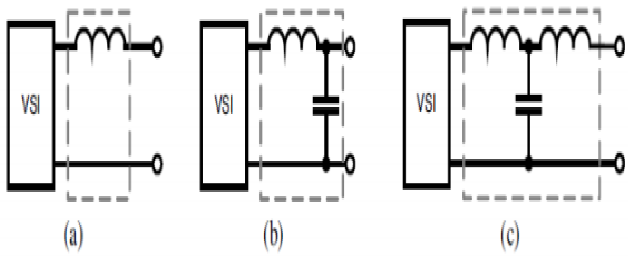


Fig -5: Filter Topologies (a) L-Filter (b) L-C Filter (d) L-C-L Filter

Table -2: Filter Components

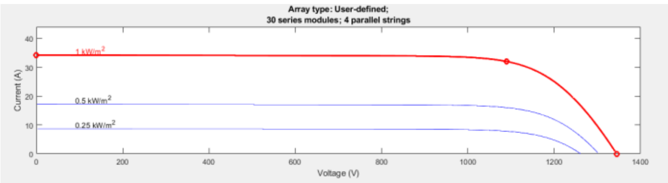
Components	Value
Inverter side inductor Li	4mH
Filter capacitor, Cf	3μF
Grid side inductor, Lg	2.4mH
Damping resistance, Rd	0.755Ω
Resonance frequency	23.4kHz

3. Designing of PV array

A solar PV array is modeled using 30 solar cells. With insolation of 1000 W/m^2, an output voltage of 19.29 V is obtained. The open-circuit voltage, Voc is 19.29 V, short circuit current is 4.75A, and output power is 75W.

3.1 Simulation diagram and results

3.1.1 PV array I-V characteristic



3.1.2 PV array P-V characteristic

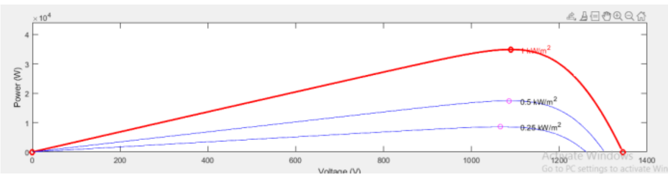
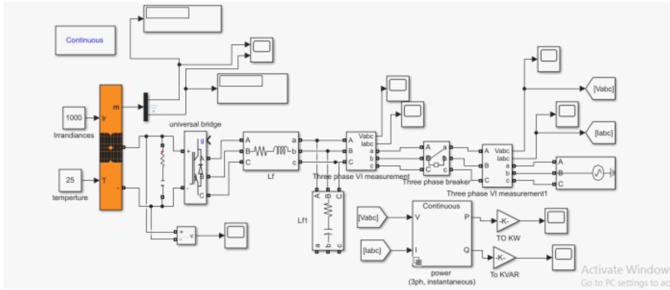


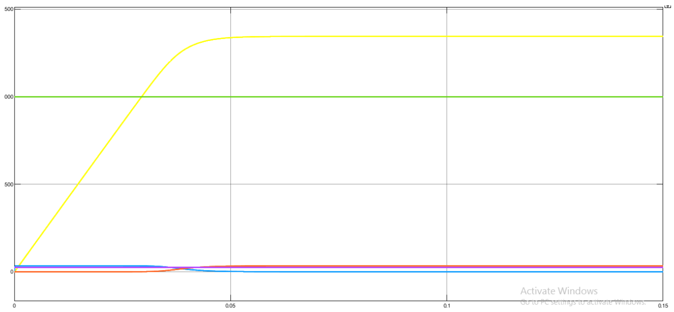
Table -3 : Output voltage of the converter with change in insolation

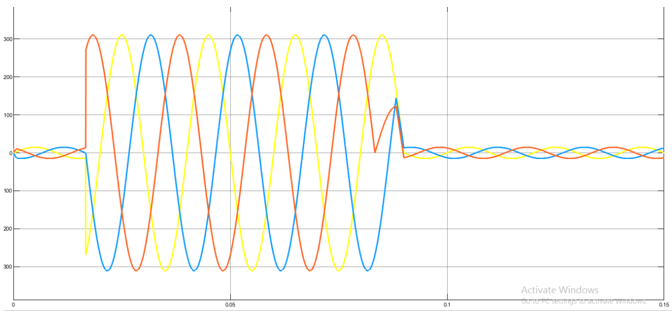
SL. NO	Insolation (W/m^2)	Output of PV array (V)	Output of the converter (V)
1.	1000	19.29	95.24
2.	900	18.21	83.21
3.	800	16.02	72.91
4.	700	14.08	65.37
5.	600	13.04	56.26
6.	500	11.92	47.09

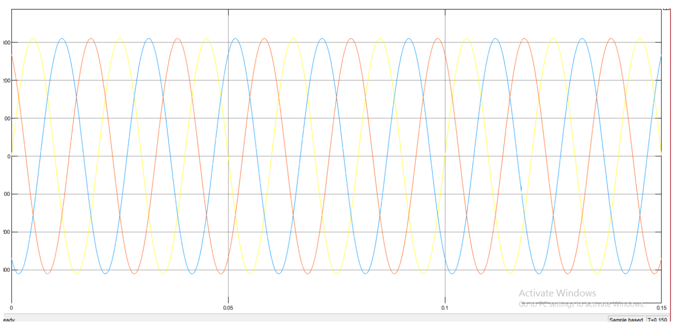
3.1.3 Matlab Simulation Circuit



3.1.4 Matlab Simulation Output waveforms







4. CONCLUSIONS

Micro-Grid (MG) system that is based on renewable power generation units is presented in this paper. The proposed system has been designed to operate in two operational modes; islanded & grid-connected. The system performance is investigated using a simulation-based on Matlab/Simulink software package. A control coordinator and monitoring system are also included to monitor the micro-grid system state and decide the necessary control action for an operational mode. The system design took into consideration cost reduction by using a single 3-phase inverter instead of three one-phase inverters. Moreover, a transformer has been eliminated to supply power to its local loads. It is intended that this work will be the base for developing more sophisticated Micro-Grid designs.

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