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MODELING OF GRID CONNECTED SOLAR PHOTOVOLTAIC CELLS FOR GENERATION OF SOLAR POWER

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ABSTRACT

Grid connected solar photovoltaic power plant is becoming common in India. Most of this has capacities ranging from a few kilowatts to tens of mega watt. Unlike in many developed countries, small grid-tied solar power plants in the range of one or two kilowatt are not being implemented in India. This paper is designed for modeling of grid-connected solar photovoltaic systems with and without energy storage, and compares the energy generation in a typical Indian scenario.

KEYWORDS: PV System, Inverters, Grid, RES

The conventional energy sources, obtained from our environment, tend to exhaust with relative rapidity due to its irrational utilization by the humanity. Renewable energy offers a promising alternative source. Solar energy seems to be most attractive now days. The quantity of energy from the sun that arrives on the earth surface in a day is ten times more than the total energy consumed by all people of our planet during a year. Photovoltaic (PV) energy has great potential to supply energy with minimum impact on the environment, since it is clean and pollution free. The grid integration of Renewable Energy Sources (RES) applications based on photovoltaic systems is becoming today the most important applications of PV systems, gaining interest over traditional stand-alone systems. Four different system configurations are widely developed in grid-connected PV power applications: the centralized inverter system, the string inverter system, the multi string inverter system and the module-integrated inverter system [1].

In the grid-connected PV system, power electronic inverters are needed to realize the power conversion, Grid interconnection, and control optimization. Generally, grid-connected pulse width modulation (PWM) voltage source inverters (VSI) are widely applied in PV systems [2-3]. For the inverter based PV system, the conversion power quality including the low THD, high power factor, and fast dynamic response, largely depends on the control strategy adopted by the grid-connected inverters [4]. The strict regulations have been applied to the equipment connected to the utility lines to maintain the grid security. Some of these regulations relate to harmonic distortion and power factor [5]. The growing use of power electronics has tendency of the harmonic distortion levels to increase [6].

Therefore the increasing integration of photovoltaic energy with electric transmission and distribution network has been a challenge for planners and researchers.

SOLAR ENERGY

For solar power, there is the natural diurnal cycle of variability in insulation [incident solar radiation]. The position of the sun influences the incidence of the solar rays on the solar cells, resulting in a noticeable variation of the power output. Also hours of sun vary with the time of the year. The solar power decreases in the autumn and winter and is higher in spring and summer. Solar energy is abundant and offers a solution to fossil fuel emissions and global climate change. Earth receives solar energy at the rate of approximately 1, 20,000 terawatt (1 TW = 1012 watt or 1 trillion watt). This enormously exceeds both the current annual global energy consumption rate of about 15 TW, and any conceivable requirement in future.

India is one of the fastest growing countries in terms of energy generation and consumption. Currently, it is the fifth largest consumer of energy in the world, and will be the third largest by 2030. India’s current RE base is 22233 MW and it is 11.66% of total installed capacity of 190.59 GW (Feb. 2012). India stands 4th in the installed power generation capacity using RE sources. The Green peace International, European Renewable Energy (EREC) reports (March, 2009) has projected that by 2050, about 69% of the electricity produced in India will come from RE sources. ‘New’ renewable– mainly wind, solar thermal energy and PV will contribute almost 40%. The Country has an estimated RE potential of around 88,081 MW from

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available exploitable sources.

Table 1: India Renewable Energy at a Glance

Renewable Energy System	Estimated Potential (MW)	Installed Capacity(MW)
Grid Connected		
Wind	48500	16179
Small Hydro	15000	3300.13
Biomass Power	16881	1142.60
Cogeneration bagasses	5000	1952.53
Waste of Energy	2700	73.46
Solar PV and Thermal	50MW/Sq.Km	481.48
Total	88081	23129.40
Off-Grid		
Waste of Energy		92.93
Biomass		347.85
Biomass Gasified		148.26
Hybrid System		1.45
Solar PV		81.01
Watermills		2025 Numbers
Total		671.50
Total(Grid Connected + Off Grid)		**23800.90**

GRID CONNECTED PHOTOVOLTAIC SYSTEM

The photovoltaic (PV) power generation systems are renewable energy sources that expected to play a promising role in fulfilling the future electricity requirements. The PV systems principally classified into stand-alone, grid connected or hybrid systems. The grid-connected PV systems generally shape the grid current to follow a predetermined sinusoidal reference using hysteresis-band current controller, which has the advantages of inherent peak current limiting and fast dynamic performance. Fig.1 shows the schematic diagram of a grid connected PV system. It typically consists of two main parts: the PV array and the power conditioning unit (PCU).

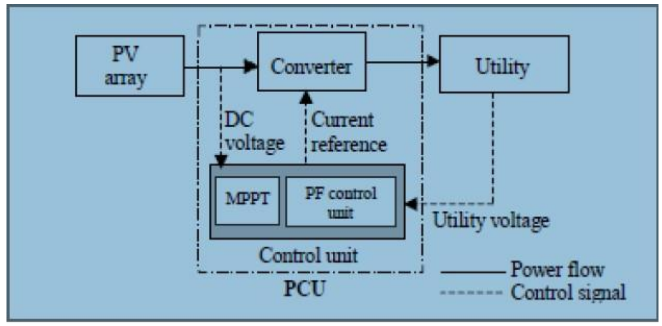

Figure 1: Schematic Diagram of Grid-Connected PV System

The PCU typically includes

- A Maximum Power Tracking (MPPT) circuit, which allows the maximum output power of the PV array.
- A Power Factor (PF) control unit, which tracks the phase of the utility voltage and provides to the inverter a current reference synchronized with the utility voltage.
- A converter, which can consist of a DC/DC converter to increase the voltage, a DC/AC inverter stage, an isolation transformer to ensure that the DC is not injected into the network, an output filter to restrict the harmonic currents into the network.

SOLAR POWER GRID CONVERTERS

Single-phase grid connection is not as simple as it would look at first sight. Regulation on injected harmonics and the efficiency of the inverter are important factors. Inverters that have a galvanic isolation by means of a transformer have a low efficiency. They are employed in many commercial grid converters and can be classified as low- voltage side transformer and high-voltage side transformer. The basic topology for a low voltage side transformer based converter.

The DC-DC convert is mostly of the type forward of Fly back, since they provide galvanic isolation through their coupled inductors. Here the transformer is a high frequency device (20 kHz) and therefore the volume of transformer is smaller than a comparable low frequency (50Hz) transformer.

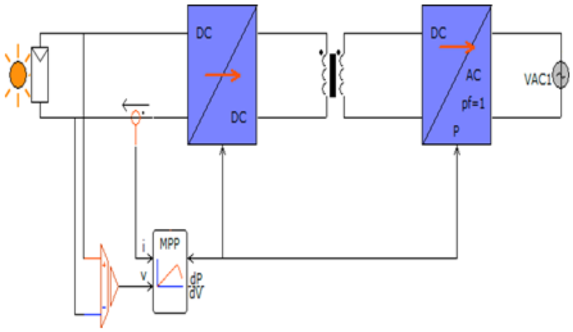

Figure 2: Low Voltage High-Frequency transformer based.

High Voltage Low-Frequency transformer based [7]. Here the transformer is larger in volume compared to the low voltage transformer design; because the operational frequency is much lower (50 Hz or 60 Hz). A typical topology for a low frequency high voltage side transformer based converter. Here the boost converter creates a sinusoidal modulated DC voltage that is connected via the coupled inductors to the main grid.

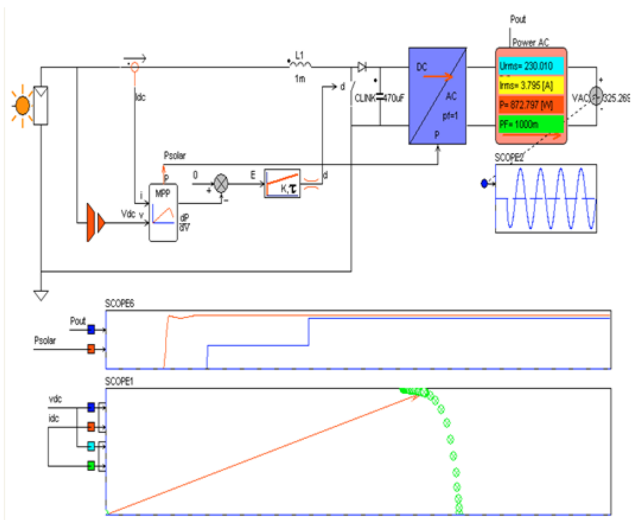

Figure 3: Transformer based design.

Although isolation comes naturally with the transformer-based designs, they have a number of disadvantages, from which efficiency is the main drawback.

GRID CONNECT SOLAR CONVERTER WITH MAXIMUM POWER POINT (MPP)

This example shows the control of a grid-connected solar system. The circuit model including the MPP control and grid-connection control.

A detailed second level circuit model that includes load dependent loss and temperature dependency models the solar module. A boost converter that regulates the MPP for the solar module electrically loads the solar module. The boost converter is also modeled as a second level circuit model. The MPP controller is a first level system model that calculates the derivative of the power as a function of the voltage of the solar module. Together with the first level system model for the PI controller, the amount of power harvested by the solar module is maximized. The last part is the grid connection. Here a first level system model for the inverter and control is used. This simulation shows the mixture between the various levels in modeling.

Since all models are connected in a circuit level model, the V-I interactions can be studied as well as the MPP control part.

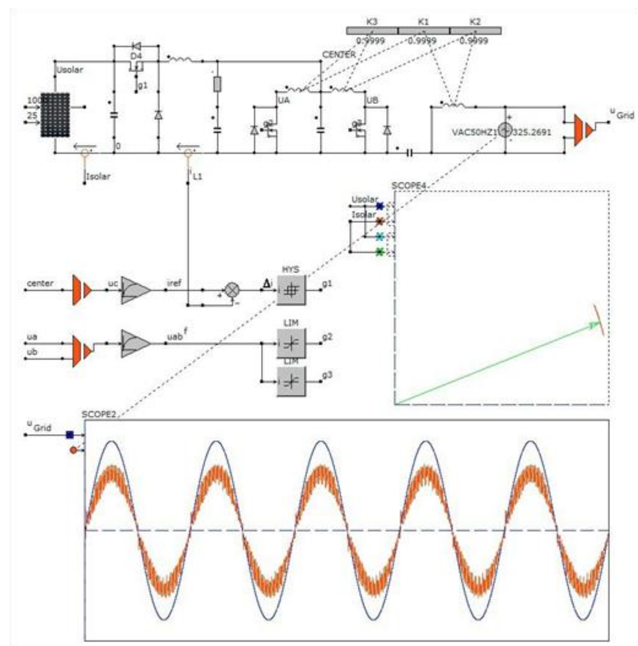

Figure 4: PV System based design with MPPT Charge controller.

The single-phase grid converter is a very simple system level model that only controls the current delivered to the single phase grid. In a more detailed study, the complete single-phase inverter with controlling algorithm and modulation strategy as well as grid synchronization could be applied.

However for studying the behavior of the MPP controller, this simplified system level model suffices. Simulation shows the V-I characteristic of the solar module. Small circles indicate the characteristic, while the arrow points to the current point of operation. Scope 2 shows the grid-side current, which is in phase with the grid voltage. The amount of power delivered by the solar module and the amount of power delivered to the grid.

Solar Module with Boost Converter, Grid Connection and MPP Control

A maximum power point tracker (or MPPT) is a high efficiency DC to AC converter that presents an optimal electrical load to a solar panel or array and produces a voltage suitable for the load.

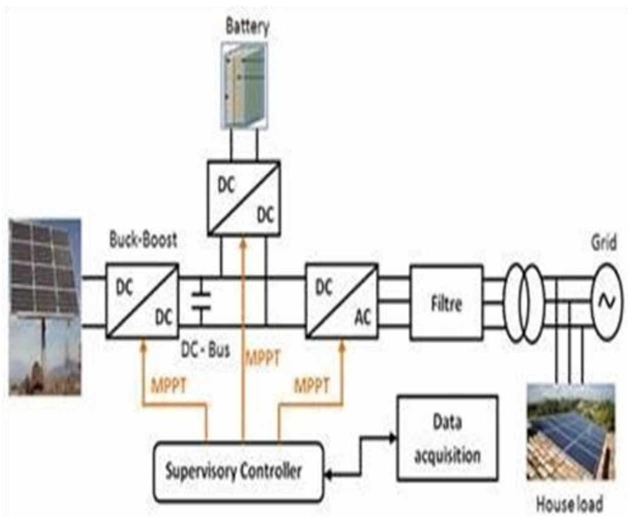

Figure 5: Boost converter with MPPT system.

Solar system comprises PV array, Boost converter with MPPT system and Voltage Source Converter (VSC).The maximum solar radiation of PV array is 1000 W/m2, and solar spectrum is 1.5 air-mass ratios. Power from PV array is calculated by following equation.

$$Ppv = IpvVpv = NpIph\ [(\frac{q}{KAT} * \frac{Vpv}{Ns})\ \text{-}1]$$

In this equation, Ppv is the generated PV power output. V**pv** is the generated output voltage, Ipv is output current. Iph is photo generated current, 5.96 A, q is charge of electron $1.602 \times 10{-}19$ C. K is Boltzmann constant, $1.381{\times}10{-}23$ J/K, A is ideality factor 2.46, T is temperature expressed in Kelvin Np, Ns is number of parallel module and series module respectively. PV array delivering a maximum of 100 kW at 1000 W/m2 sun irradiance. 5-kHz boost converter increasing voltage from PV natural voltage (272 V DC at maximum power) to 500 V DC.

CONCLUSION

Modeling of grid connected converters for solar energy requires not only power electronics technology, but also detailed modeling of the grid synchronization and modulation techniques.

Control of active and reactive power in both single and three phase grid connections can be achieved by quadrature controllers, analogous to field oriented control in electrical drives. Modulation strategies, loss determination and thermal cycling, as well as life time estimation are important factors that can be studied into detail. This article has presented a comprehensive literature review on important aspects of grid-connected photovoltaic system such as modeling of photovoltaic array, maximum power point tracking, inverter etc. It is expected that better methods of modeling and control design will make the photovoltaic system more efficient for Grid integration.

REFERENCES

M. Godoy Simoes, N.N. France Schetti, and M.Fried Hofer, A fuzzy logic based photovoltaic peak power tracking controller, IEEE Renewable Energy, 1998, pp. 300-305.

Y.C. Kuo, T.J. Liang, and J.F. Chen, Novel maximum power point track ing controller for photovoltaic energy conversion system, IEEE Transactions on Industrial Electronics, Vol. 48, No. 3, 2001, pp. 594-601.

Bauer, P &Duijsen, PJ van (2005). Challenges and advances in simulation. In s.n. (Ed.), Proceedings of the 36th power electronics specialists conference (pp. 1030- 1036). Piscataway, USA: IEEE.

Bauer, P &Duijsen, PJ van (2008). Power electronics simulations. International review on computers and software (IRECOS), 3(3), 307-314.

Duijsen, P van, Bauer, P & Chen, F (2006). Modeling and simulation for wind energy. In s.n. (Ed.), Proceedings of the Taiwan power electronics conference & exhibition (pp. 1087-1092). Taipei: Taiwan Power Electronic Association/IEEE Taipei Chapter.

J. saloman & T.S. Sirish, Performance Analysis of Grid Connected Solar Photo-Voltaic System under Grid Abnormal Conditions, International conference on Signal Processing, Communication, Power and Embedded System (SCOPES)-2016 pp-1-7.

F.E. Tahiri, K. Chikh1, M. Khafallah, A. Saad and D. Breuil, Modeling and performance analysis of a solar PV power system under irradiation and load variations, 2017 14th International Multi-Conference on Systems, Signals & Devices (SSD) 978-1-5386-3175-1/17, 2017 IEEE.