Simulation of Power Grid Integrated With Renewable Energy Source

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Abstract- *The Aim of This Paper is to Model and Simulate a 300 KW Solar Photovoltic Power Plant Integrated with Electricity Grid. This System Analyzes The System:s performance and Address challenges Assosiated with Solar Inverters and Grid Integration. By Using MATLAB/Simulink, it Provides a virtual platform to Design, Test and Optimize PV Systems. It Analyzes the process of converting Sunlight into electricity through PV Panels and Evaluates the efficiency of inverters in transforming DC power into AC for Grid.*

Keywords- Solar Photovoltaic System, MATLAB/Simulink, MPPT, Grid, Integrated with Solar PV System.

I. INTRODUCTION

Solar Power Plant are Energy Generation System that convert sunlight into electricity, offering a clean, renewable, and sustainable source of energy. They play crucial role in addressing the growing demand for electricity while mitigating the environmental challenges posed by fossil fuel-based energy production. By connecting the abundant and free energy of the sun, solar power plants contribute to reducing greenhouse gas emission, promoting energy independence and advancing global sustainable goal. Smart Grid is an integration of 3 Technologies Namely: Electrical Technology, Information Technology, Communication Technology. It is required to maintain proper balance between Load and Generation. i.e. Demand and Supply.

These use solar panels composed of photovoltaic cells to convert sunlight directly into electricity. PV system is modular, scalable, and widely used for various application from residential rooftop to large scale solar farms. Concentrated Solar Panels (CPS) is used to mirrors or lenses to concentrate sunlight onto receiver that heats a fluid, which is then used to produce stem and drive a turbine to generate electricity.

A Grid-connected solar power plant is a renewable energy system designed to generate electricity from sunlight and supply it to public electricity grid. The system primarily consists of solar panel that capture sunlight and convert into direct current (DC). This DC power is then transformed into alternating current (AC) through inverter, making it compatible with grid requirement.

II. METHODS AND MATERIAL

Overview of Solar PV System

The Integration of solar photovoltaic (PV) systems into energy networks involves evaluating their technical, economic, and environmental aspects to ensure efficiency and sustainability. Simulations and case studies play a crucial role in understanding PV performance and their interaction with other energy components. Key elements of integration include modelling energy generation based on real-world conditions like solar irradiance, temperature, and shading, as well as incorporating advanced technologies such as bifacial panels Using MATLAB Software R2024.

SYSTEM MODEL

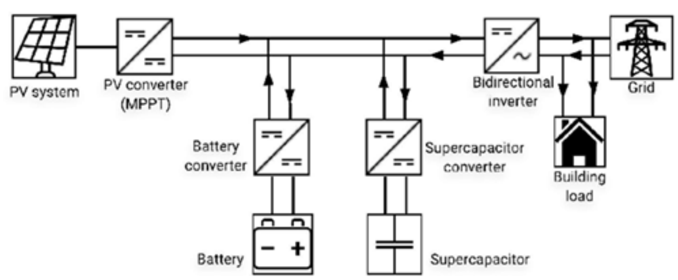

Fig 1: Circuit Diagram of Grid Connected Solar PV System

The Fig illustrates a hybrid energy system designed to integrate a PV system with energy storage device, building loads and power grid. Solar energy is captured by PV system and its output is regulated by PV converter with Maximum Power Point Tracker (MPPT).

The regulated DC power is distributed through a DC bus to various components. A battery connected it stores energy for later use, providing backup during periods of low generation or high demand. A bidirectional inverter connect system to building load and power grid, enabling the conversion of DC TO AC power for load or exporting excess energy to grid. The system dynamically manages energy flow among generation, storage, and consumption to ensure efficient operation and reliability.

ACTUAL SYSTEM MODEL

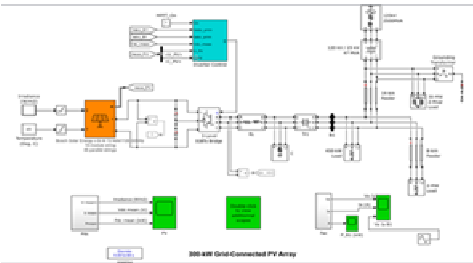

Fig 2: Simulation Model of 300kW Grid-Connected Solar Power Plant

PV Solar Power Plant Capacity: 300KW, No. of PV Module: 924, Capacity of Each Module: 325Watt Parallel String: 48 and Series String: 19, Load: 450 KW, Inverters: 6 No's, Make: ABB Installed and Commissioned By: BOSCH Ltd.

Calculation Formula:

1.Power Flow Equation, $P=VI\cos(\phi)$
2.Solar Power Output, $PPV=G\times A\times\eta$
3.Reference Voltage, Vref=Vmpp+Kp·(Vmpp−Vinv)+Ki·∫(Vmpp−Vinv)dt
4.Reference Current, Iref=Impp+Kp·(Impp−Iinv)+Ki·∫(Impp−Iinv)
5. P = V*I
Irradiance = 1000w/m2 and Temperature 45,25,35 Degree Celsis.

III. RESULTS AND DISCUSSION

In This Paper, The Simulation Model Run and Then Their Results gives a Waveforms, Observation Table, Result Analysis Justification also Obtained.

1. Observation Table

Irradiance (W/m^2)	Temperature (Degree Celsius)	Voltage (V)	Current (I)	PV Power (KW)	Grid Output (KW)	Power Factor (PF)
1000	45	816 V	412 A	300	267	0.89
1000	25	720.1	386.4	278	220	0.79
1000	35	687.457	385.782	265	230	0.87
900	25	717	367	263	298	0.88

2. Result Analysis Justification

Simulation Parameters	Method Used	Performance Outcome	Remarks
Input Voltage	Boost Converter	1000V DC	Voltage Successf Work
Input Power	PV Solar Module	300 KW	Grid Losses Nagl
Power Tracking	MPPT Algorithm	99% Efficiency	Ensures Max. Po Extraction
Output Voltage	Inverter	320/480 V AC	Grid Compatible Output
Grid Integration	Synchronization Algorithm	Stable	System Maintain Stability
Output Frequency (Hz)	Frequency	50Hz	Synchronized wi Grid
Solar Inverter	String Inverter	50KW & 6 Nos.	High Efficiency, Maintain Unity P

3. Parameters and Their Values

Parameters	Value
Total Installed Capacity	300 KW
No. of PV Modules	924 Modules (325 or 305 Wp Each)
MPPT Efficiency	99%
Inverter Efficiency	98%
THD (Voltage)	THD = 0.09%, Fundamental (50 Hz) = 2.023e+04
Power Factor Maintained	0.6-0.99

This Model is designed for Analyzing:

Efficiency of PV systems under varying irradiance and temperature. Impact on grid stability of connecting renewable energy sources. Load management and optimization for grid-connected PV systems.

Results of Simulation

1. **Characteristics of the Array at Two Different Temperatures (45 25 Deg)**

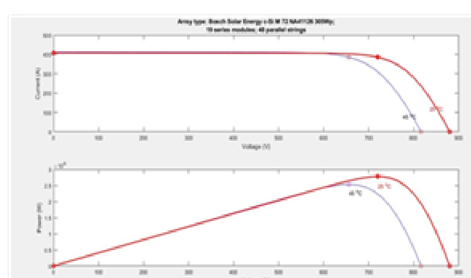

Fig 3: It Provides a detailed depiction of the Current-Voltage (I-V) and Power- Voltage (P-V) characteristics of the Bosch PV array under different temperature conditions. The top graph represents the I-V curve, while the bottom graph illustrates the P-V curve. These curves are essential for understanding the performance of the PV system and its behavior under varying environmental conditions.

2. **AC Output Power of the PV System**

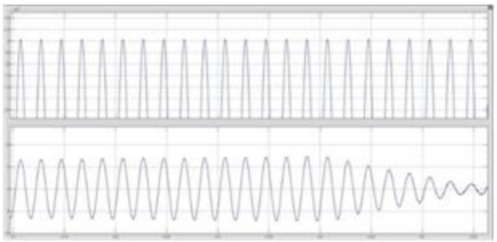

Fig 4: The AC power output, measured in kilowatts, represents the electrical power delivered to the grid or load after conversion from DC power by an inverter.

1. **DC Output Power of the PV System**

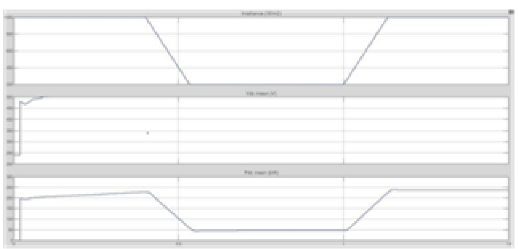

Fig 5: Shows the dynamic behavior of a photovoltaic (PV) system responding to changes in solar irradiance, highlighting how irradiance affects the system's DC voltage and DC power. It consists of three subplots: Irradiance(w/m2), DC Voltage, DC Power.

2. **VSC Control**

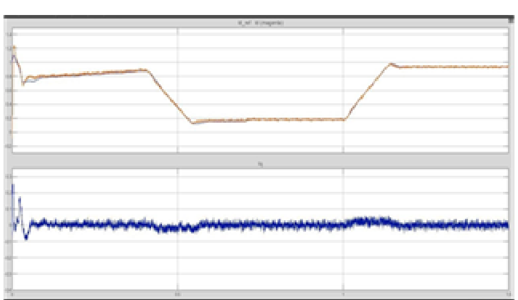

Fig 6: It refers to the control system That manages the inverter which converts DC from Solar into AC from Grid. DC link Voltage ref: 800 V, Active Power: 300000 W (300 KW) and Unity PF Used.

3. **Subsystem Phase A**

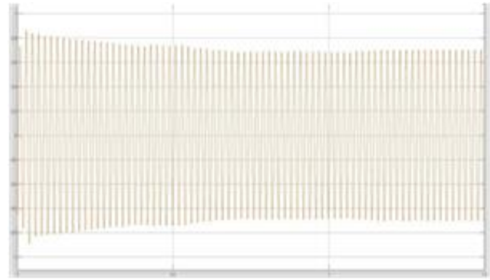

Fig 7: Shows That Voltage is usually Sinusoidal, Current From inverter to grid connect, Power Delivery and it can verify Harmonics and Waveform Distortion at 50 Hz (230 Vrms*root2).

3. **Sinewave Graph, Va, Ia, Vs Time**

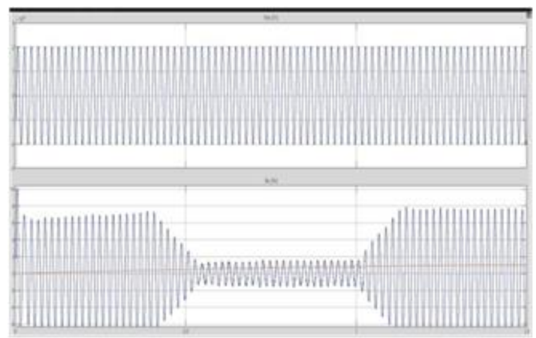

Fig 8: The Graph Shows That Va (AC Voltage Phase A) & Ia (AC Current Phase) Should Appear as Sinewaves usually Synchronized with Grid Frequency (50 Hz). If Inverter is properly synchronized va & ia will be in phase and have fixed power factor and Time shows that Horizontal Axis (0-2 Sec).

4. **FFT Analyzer Graph**

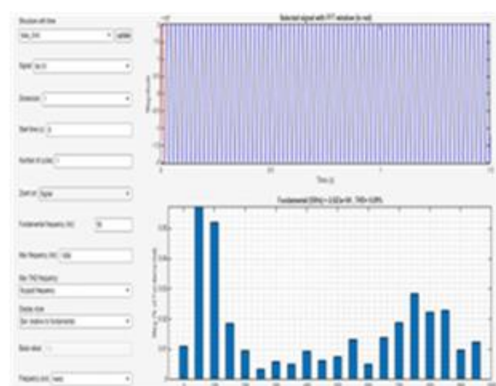

Fig 9: In a grid-connected 300 kW solar PV system, an FFT Analyzer, particularly within MATLAB, is used to

Analyze the harmonic content of the grid-connected voltage and current waveforms. This helps in identifying and mitigating power quality issues like harmonic distortion that can arise due to the system's inverters. In FFT Analyzer Graph, THD is 0.09% & 50Hz=2.023e+04.

IV. CONCLUSION

In This Paper, The Conclusion of Smart Grid Technology is essential for seamlessly integrating renewable energy source into power grid enabling a more sustainable and resilient energy system. By facilitating efficient and reliable integration of variable and distributed energy source, smart grid is crucial for transitioning towards cleaner energy source and reducing reliance on fossil fuels.

The conclusion effectively summarizes the comprehensive process of simulating and designing a 300kW solar power plant. Effective Power Generation. The MATLAB Simulation of 300 KW Grid Connected Solar System: Technically Feasible, Stable Under Varying Conditions, Effective in Real Time Power Injection, Compliant with Grid Codes and Safety Standards. In essence, this comprehensive approach ensures that a 300kW solar power plant can meet modern energy demands while supporting global transitions toward clean energy solutions.

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