Dynamic Power Quality Assessment of Single and Two-Stage Grid-Connected PV Inverters in Synchronous Reference Frame

GUGULOTH SHIRISHA [1] | DR D.SIVA PRADAD[2]

[1]Pg Scholar, Dept of EPS, Kodada Institute of Technology & Science for Women-Kodad, Telangana.

[2] Assistant Professor, Dept of EEE, Kodada Institute of Technology & Science for Women-Kodad,Telangana.

ABSTRACT: Numerous studies were conducted to enhance the functioning of solar power systems, which use sustainable and renewable energy sources to meet power demand. By examining the nominal current and voltage output from the inverter under various weather circumstances and switching frequencies, the power system quality will be examined in this study to demonstrate the effect of power quality on the electrical grid. One of the main problems that must be solved is power quality. Economic costs and disruptions could result from poor power operation. MATLAB/Simulink will be used for the real-time simulation.

KEYWORDS: RENEWABLE ENERGY, POWER QUALITY, PV INVERTERS, GRID.

I.INTRODUCTION: The PV system is made up of solar cells that use semiconductor materials to produce specific power based on P-V and I-V characteristics. These cells transform solar energy in irradiance form into electrical energy.[1]. Figure 1 depicts the PV cell's equivalent circuit, which includes a diode, series resistance, parallel resistance, and photocurrent, which stands in for the current source. Below are the equations for the analogous circuit [2][3][4].

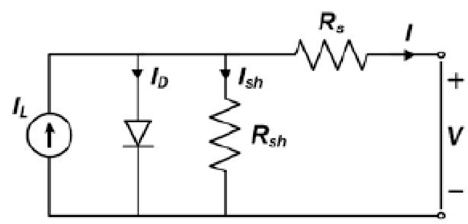


FIG 1 the equivalent circuit of the PV cell

$$I = I_{ph} - I_s\left[e^{\frac{q(V+IRs)}{A.K.T}} - 1\right] - \left[\frac{V+IRs}{Rsh}\right] \qquad (1)$$

$$I_{ph} = [I_{sc} + K_i(T - T_{ref})].\left[\frac{G}{1000}\right] \qquad (2)$$

$$I_s = I_{rs}\left[\frac{T}{Tref}\right].e^{\left[\frac{qEg}{A.K}X\left(\frac{1}{Tref} - \frac{1}{T}\right)\right]} \qquad (3)$$

$$I_{rs} = \frac{Isc}{e^{\frac{qVoc}{Nser.K.A.T}} - 1} \qquad (4)$$

T is the PV cell temperature in Kelvin, Is is the saturation current, Irs is the reverse saturation current, Rs is the series resistance

(Rs), and sh is the parallel resistance. Light-generated current is represented by Iph, short-circuit current by Isc, open-circuit voltage by voc, thermal voltage by V, and electron charge constant Q by 1.60217646 × 10−19 C. where A is the diode ideality factor and k is the Boltzmann constant, which is equal to 1.3806503 × 10−23 J/K. As seen in figure 2 below, PV output power fluctuates when solar radiation varies between 0 W/m2 and 1000 W/m2 due to a variety of factors, including temperature and weather.

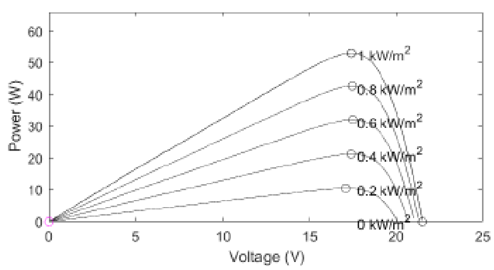


FIG 2 PV Power variation under veining solar radiation.

The photovoltaic power system's output is extracted as DC power; inverters are required to convert this DC source to AC. In the sections that follow, we will first link the grid to the PV system using a single-phase DC-AC inverter (single stage), and then we will reconnect it using a DC-DC boost converter (two stage).

II.LITARATURE SURVEY: 1) Control Techniques for the Maximization of Power Converter Robustness and Efficiency in a Parallel Photovoltaic Architecture

A parallel linked photovoltaic (PV) architecture makes use of dedicated dc-dc converters to attach character PV panels in parallel to a high voltage inverter enter bus. The sizable voltage increase regularly acquired by using connecting panels in series to the inverter enter is supplied via these per panel parallel PV converters. The advent of control algorithms that optimize a parallel PV converter's robustness and strength harvesting while adhering to most power and modern boundaries is the purpose of this thesis. Several new algorithms and analytical findings should be developed so that it will achieve this goal. An accurate model of the parallel converter dc transformer circuit is created the usage of a brand new state aircraft method that consists of generalized diode reverse recovery, considerably outperforming in advance modeling strategies. It is demonstrated that current perturb and study (PO) most power point tracking algorithms are hampered with the aid of tiny local maxima within the measured PV electricity curve known as traps.

2) Modern Maximum Power Point Tracking Techniques for Photovoltaic Energy System

Both valuable strength flora connected to the electrical grid and masses in far flung locations have been fed by means of solar photovoltaic power systems (PVES). Numerous research had been conducted to lower the rate of the strength produced with the aid of PVES. Reducing the price of generated strength with the aid of growing the generated strength from the PVES through altering its performance operations is one of the maximum crucial factors of research attempt. This can be achieved with the aid of tracking the most strength that the PV structures can produce, which could considerably increase the amount of power produced by PVES and decrease its cost. The most strength point tracker (MPPT) is the device used to screen the most energy that may be received from the PVES. To make sure that it pulls the best power possible from the PVES, MPPT employs a controlled approach to modify the power electronics converters. Traditional MPPT methods, such as perturb and take a look at, hill climbing, incremental conductance, and many others., have been first used a long time ago and have been pretty powerful for unshaded PVES. However, while there may be partial shading, the PV array's P-V curve develops many peaks, which might also motive the conventional strategies to fall interior one of the neighborhood peaks. This restrict may be addressed with the improvement of synthetic intelligence, tender computing, and metaheuristic tactics. Metaheuristic equipment can song the global peaks in shaded or unshaded PVES, which has become a brand new trend within the tracking of the maximum energy of the PVES.

III.PROPOSED SYSTEM: In the single level, the PV system is without delay related to the inverter; inside the double degree, the PV is attached to a DC-DC raise converter in order to alter the dc voltage. Along with the inductor and capacitor, the DC-DC raise converter has semiconductors: a diode and a MOSFET. The following equations are mentioned so that it will approximate the parameter of the DC-DC increase converter:

$$Ca= \frac{D.Vpv}{4.\Delta Vpv.f^2.\ Idc} \tag{5}$$

$$D=1-\frac{Vpv}{Vdc} \tag{6}$$

$$La= \frac{Vpv.(Vdc-Vpv)}{\Delta ILa.f.Vdc} \tag{7}$$

$$\Delta ILa= 0.13.\ Ipv.\frac{Vdc}{Vpv} \tag{8}$$

$$C1 \geq \frac{Ppv}{\Delta Vo.f.\ Vdc} \tag{9}$$

The PV array's output voltage is denoted by way of VPV, its most current by way of IPV, its strength by means of PPV, its switching frequency via fs, and its link capacitance with the aid of Ca. C1 is the DC hyperlink capacitance, la is the increase converter inductor, Vdc is the converter's output voltage, and D is the boost converter's duty cycle, that's controlled by an MPPT controller. $\Delta V0$ is the output voltage ripple, ΔILa is the raise inductor ripple current, and ΔVPV: The variation in PV voltage.

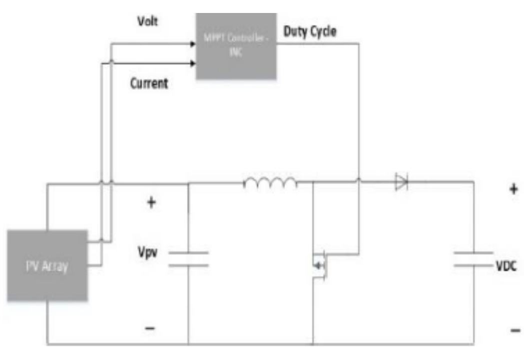


FIG 3 PV systems with a boost converter.

Many research had been carried out on Vsc. The majority of industrial sectors for a range of uses at some stage in the last few a long time. In most power applications, 3-section, and two-stage inverters are the maximum famous topology. The first studies of modern-day voltage supply multilevel converters were conducted. Control and power conversion the use of electricity electronics have emerge as increasingly crucial in RES applications because of growing energy desires and power great and efficiency. The maximum famous modulation methods for coping with these styles of converters are area vector modulation (SVM) and pulse width modulation (PWM). Predictive manage is appropriate for power converter manipulate due to some of blessings, which include its simplicity of comprehension and use, as well as its adaptability to one of a kind varieties of multilayer voltage supply converters. The creation of present day rapid microprocessors has made predictive manipulate for multilevel VSC viable, despite the fact that it necessitates more computations than traditional control strategies. The diagram underneath illustrates how the RL clear out is hooked up to the two-stage voltage supply converter.

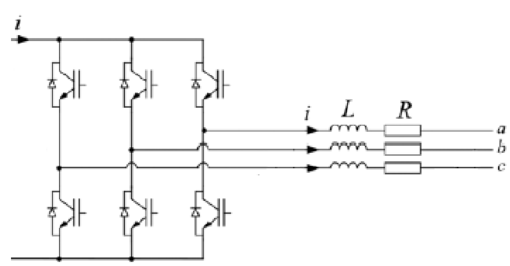


FIG 4 two-level voltage source converter is connected to RL filter

A single-level conversion, as visible in the determine underneath, and a double-degree conversion, as seen in parent 8, are used to hyperlink the PV machine to the grid. The DC-AC -stage voltage supply converter and RL clear out are used to connect the PV system to the grid after connecting it in a single step to the dc link capacitor. In order to alter the voltage inside the 2d degree, we established a DC-DC improve converter. We extensively utilized an MPPT controller to maximise energy extraction during weather fluctuations.

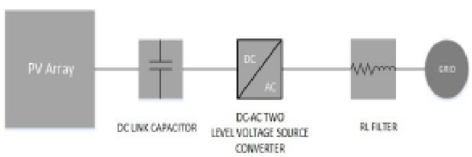


Fig 5 Single Stage Conversion

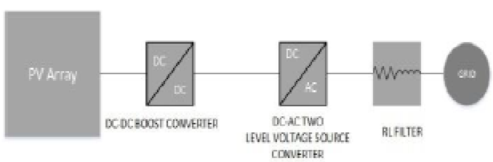


Fig 6 Double Stage

The PV array, DC link capacitor, DC-DC boost converter, DC-AC two-level voltage source converter, and RL filter parameters are listed in Table 1.

Table 1: System parameters.

PV array parameters (0.997 MW)	
Parallel strings	238
Series-connected modules per string	79
Maximum Power (W)	53.07
Cells per module (Ncell)	80
Open circuit voltage Voc (V)	21.5
Short-circuit current Isc (A)	3.33
The voltage at maximum power point Vmp (V)	17.4
Current at maximum power point Imp (A)	3.05
Temperature coefficient of Voc (%/deg.C)	-0.3616
Temperature coefficient of Isc (%/deg.C)	0.041509
Irradiances (W/m2)	1000
Temperature cell (deg. C)	25
Model Parameters	
Light-generated current IL (A	3.3406
Diode saturation current I0 (A)	$1.1349e^{-10}$
Diode ideality factor	0.43473
Shunt resistance Rsh (ohms)	150.0427
Series resistance Rs (ohms)	0.4757
Boost Converter Parameters	
DC Link Capacitor	3 mF
Inductance	2 µH
Outer Capacitor	3 mF
DC Voltage (DC-DC boost output voltage)	1250 V
Switching Frequency	20 KHz
PWM Generator Parameters	
Switching Frequency	3420 HZ
RL filter Parameters	
Inductance (H)	$1.0000e^{-4}$
resistance Rs (ohms)	$7.5000e^{-4}$
Two-Level Converter Parameters	
Device on-state resistance (Ohms)	$8.8000e^{-4}$
Snubber resistance (Ohms)	$1e^{6}$
resistance (Ohms)	0.00163
time constant	0.0020
grid	
Amplitude	3.9191
System parameters Parameters	
real power (watt)	1000000
reactive power	0

Figure nine suggests a schematic illustration of a grid-imposed frequency VSC system. The VSC is modeled with the aid of a lossless power processor that includes an equal DC-bus capacitor, a modern source that represents the VSC switching electricity loss, and a series on-state resistances on the AC facet that represent the VSC conduction power loss. The VSC -degree represents a DC-side voltage equalizing scheme. A DC voltage supply can be related to the DC facet of the VSC. Every section of the VSC is hooked up to the AC machine thru a sequence RL department.

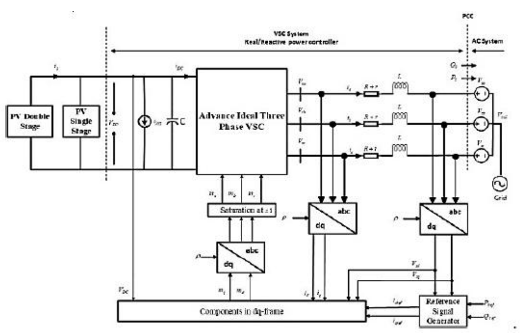
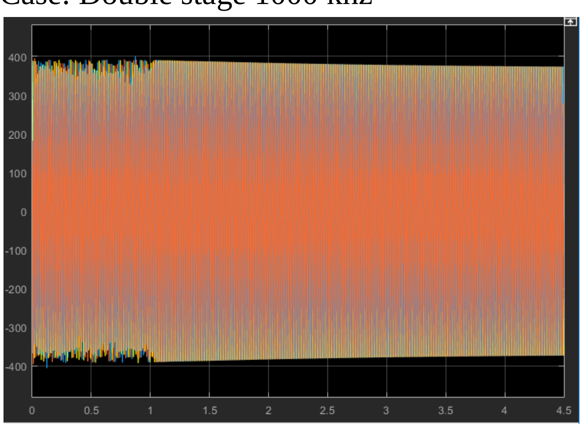


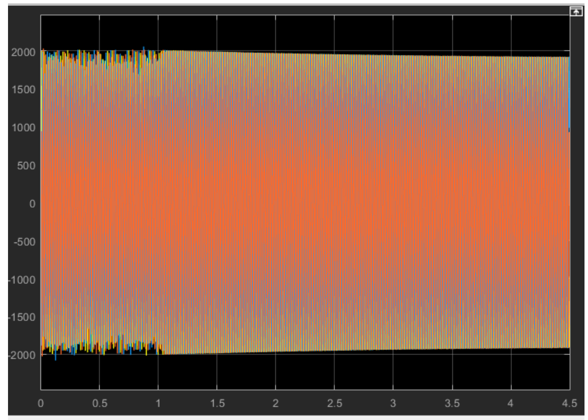
Fig 7 Control System

IV.SIMULATION RESULTS:

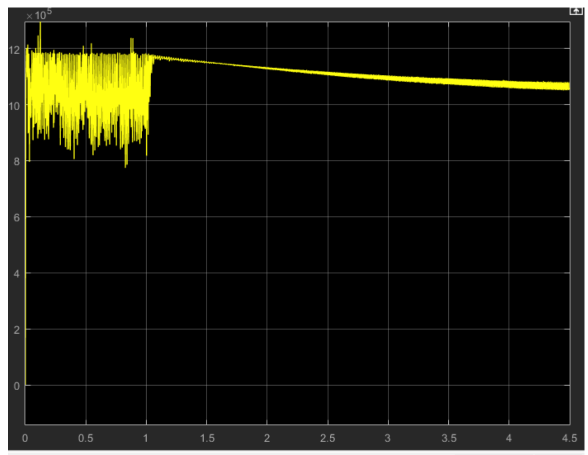
Case: Double stage 1000 khz



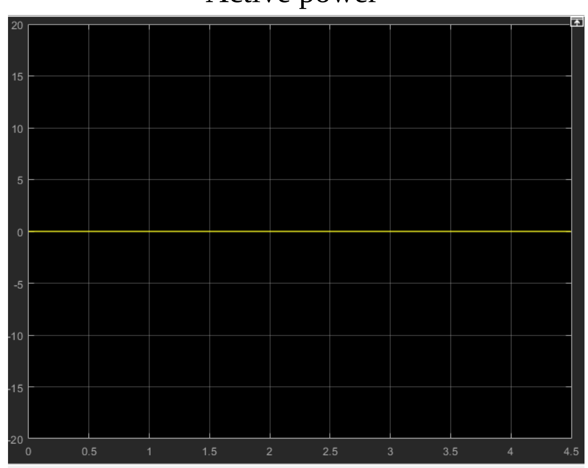
Grid voltage



Grid current

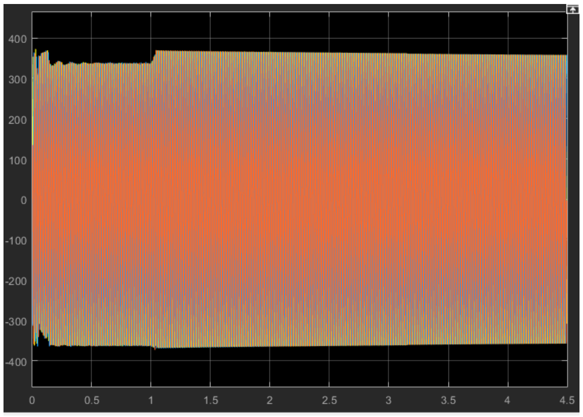


Active power

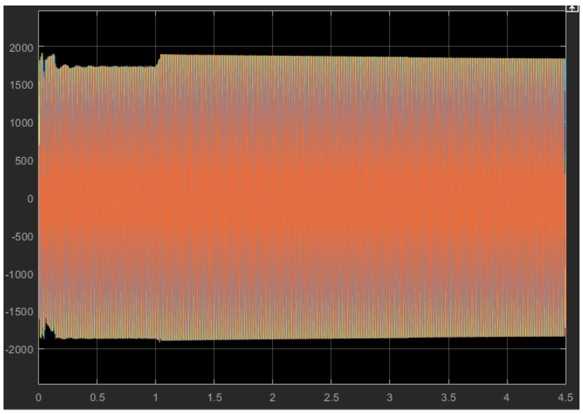


Reactive Power

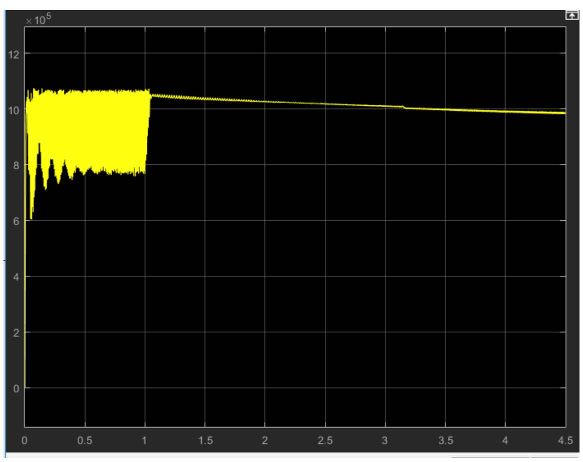
Case: Double stage with 3420khz



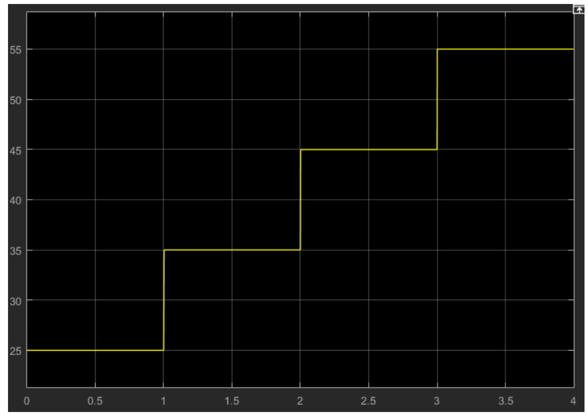
Grid voltage



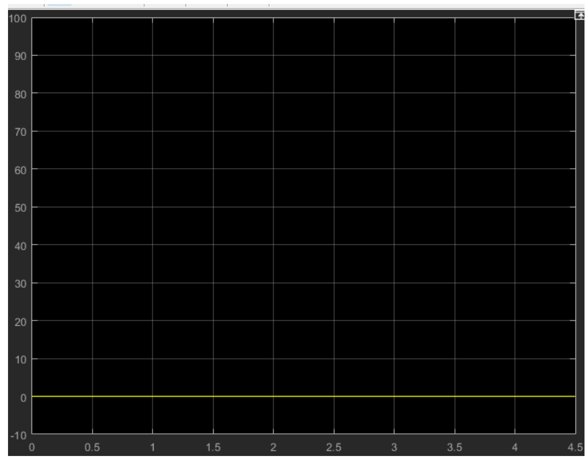
Grid current



Active

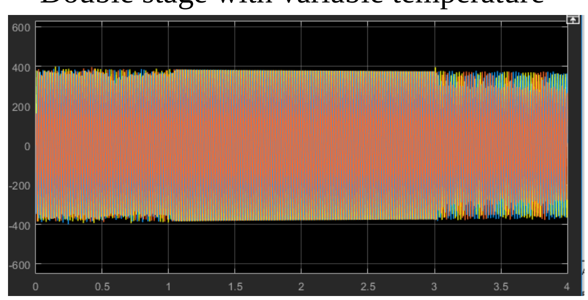


power

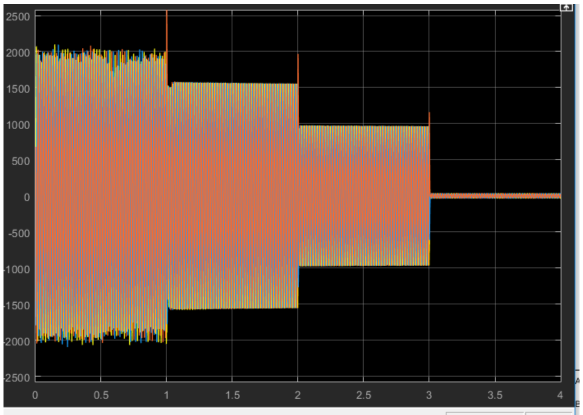


Reactive power

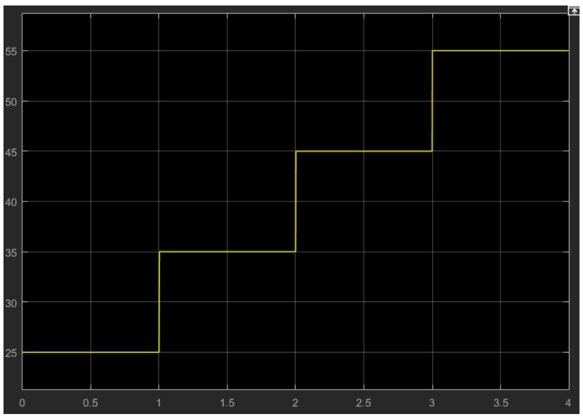
Double stage with variable temperature



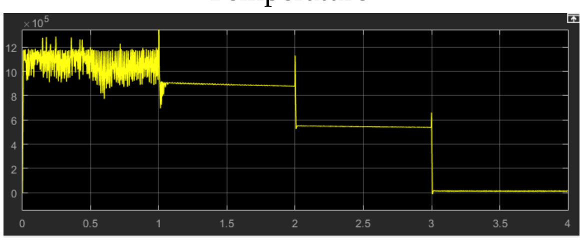
Grid Voltage



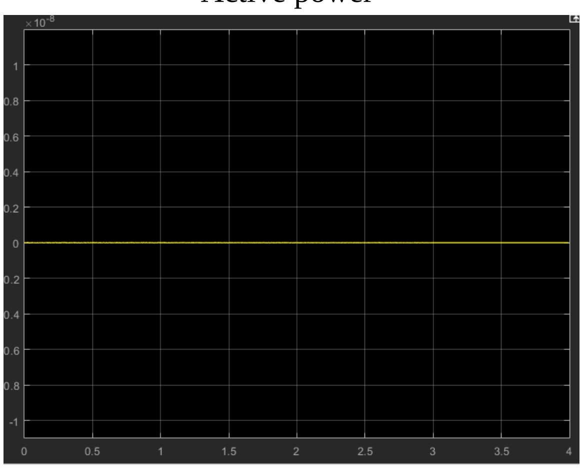
Grid Current



Temperature

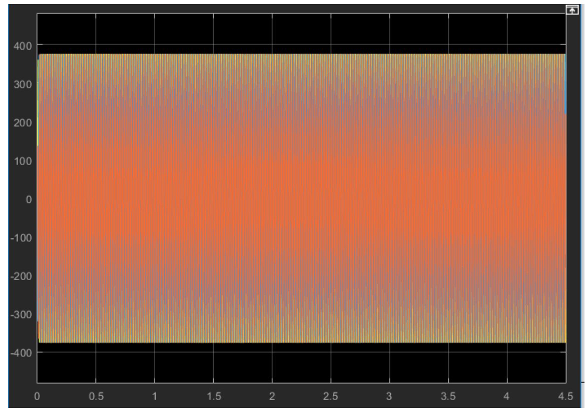


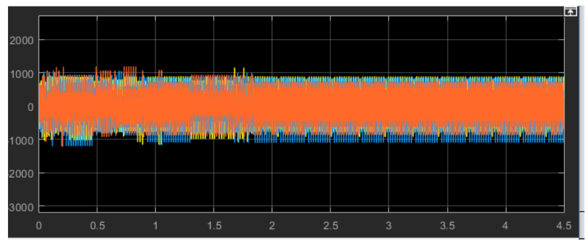
Active power



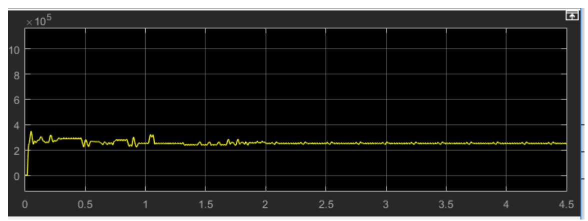
Reactive power

Single stage3420 KHZ

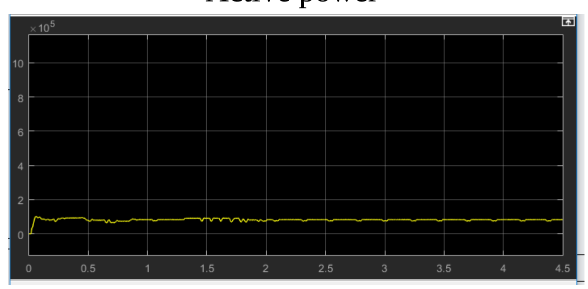




Grid current

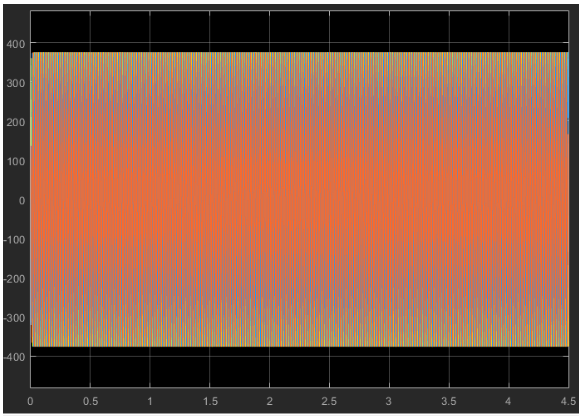


Active power

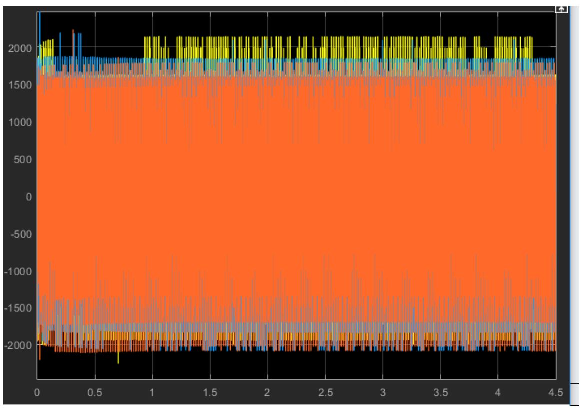


Reactive power

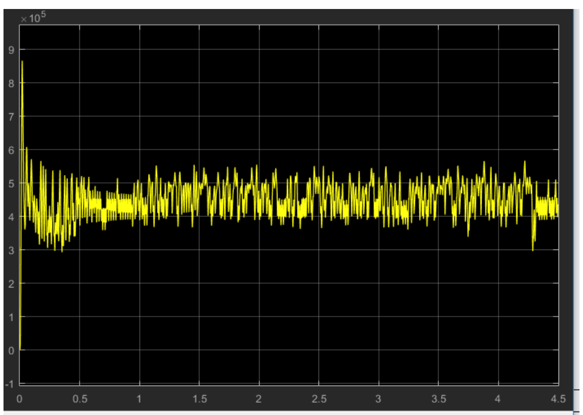
Single stage 1000khz



Grid voltage



Grid Current



Active power

V.CONCLUSION: A vital part of grid-connected microgrids (MG) are voltage source converters (VSC). They link the electric grid to distributed-generation (DG) units. However, the effective operation of the VSC rapid response depends on reliable and stable controllers. To control instantaneous real and reactive power, a number of power controllers for grid-connected MGs VSCs have been developed; nevertheless, most of these controllers rely on two-level converters. The purpose of this study is to examine the nominal current and voltage output from the inverter at Stander Test Condition (STC) under the influence of changing temperature and radiation conditions in single and double stages, with the THD being equivalent in both control strategies. Next, we examined the system at switching frequencies of 3420 Hz and 10 kHz. We discovered that the PV was controlled by the double stage approach, and the current was reduced at 3420 Hz. In both single and double stages, the current and power dropped when the switching frequency was increased to 10 kHz. MATLAB/Simulink was used to simulate the grid in order to examine power quality and system performance.

REFERENCES: [1] D.C. Jones, Control Techniques for the Maximization of Power Converter Robustness and Efficiency in a Parallel Photovoltaic Architecture, Colorado, 2013

[2] T. Salmi, M. Bouzguenda, A. Gastli, A. Masmoudi, Matlab/Simulink based

modeling of photovoltaic cell. Int. J. Renew. Energy Res. 2(2), 213–218 (2012)

[3] Elbaset, A. A., Abdelwahab, S. A. M., Ibrahim, H. A., & Eid, M. A. E. (2020). Performance analysis of photovoltaic systems with energy storage systems (1st ed.). Springer Nature.

[4]Eltamaly, A. M. (2020). Modern Maximum Power Point Tracking Techniques for Photovoltaic Energy Systems. (A. Y. Abdelaziz, Ed.). Springer Nature Switzerland .

[5] Elbaset, A. A., Abdelwahab, S. A. M., Ibrahim, H. A., & Eid, M. A. E. (2020). Performance analysis of photovoltaic systems with energy storage systems (1st ed.). Springer Nature

[6] D.W. Hart, Power Electronics (Tata McGraw-Hill Education, Valparaiso, 2011)

[7] A. Nabae, I. Takahashi, and H. Akagi, 1981. A new neutral-point-clamped PWM inverter, IEEE Trans. Ind. Applicat., IA(17):518 – 523, Sept./Oct. 1981.

[8] G. Carrara, S. Gardella, M. Marchesoni, R. Salutari, and G. Sciutto, "A new multilevel PWM method: a theoretical analysis," IEEE Transactions on Power Electronics, vol. 7, no. 3, pp. 497– 505, Jul. 1992.

[9] B. P. McGrath and D. G. Holmes, "Multicarrier PWM strategies for multilevel inverters," IEEE Transactions on Industrial Electronics, vol. 49, no. 4, pp. 858–867, Aug. 2002.

[10] R. Tallam, R. Naik, and T. Nondahl, "A carrierbased PWM scheme for neutral-point voltage balancing in three-level inverters," IEEE Trans. Ind. Appl., vol. 41, no. 6, pp. 1734–1743, Nov./Dec. 2005.

[11] V. Yaramasu, B. Wu, M. Rivera, and J. Rodriguez, "Predictive current control and DC-link capacitor voltages balancing for four-leg NPC inverters," Industrial Electronics (ISIE), 2013 IEEE International Symposium on, Tehran, pp.1-6, 28-31 May 2013

[12] J. Rodríguez, and C. Cortés, Predictive control of Power Converters and Electrical Drives (UK: A Johan Wiley & Sons, Ltd., 2012).

[13] V. Najmi, S. Ebrahimi, and H. Oraee, "Output voltage quality intensification of diode clamped multilevel inverters using FM PWM technique," Power Electronics and Drive Systems Technology (PEDSTC), 2012 3rd, pp.98 – 102, 15- 16 Feb. 2012

[14] Amirnaser Yazdani, Reza Iravani - Voltage-sourced converters in power systems- modeling, control, and applications (2010, IEEE Press-John Wile