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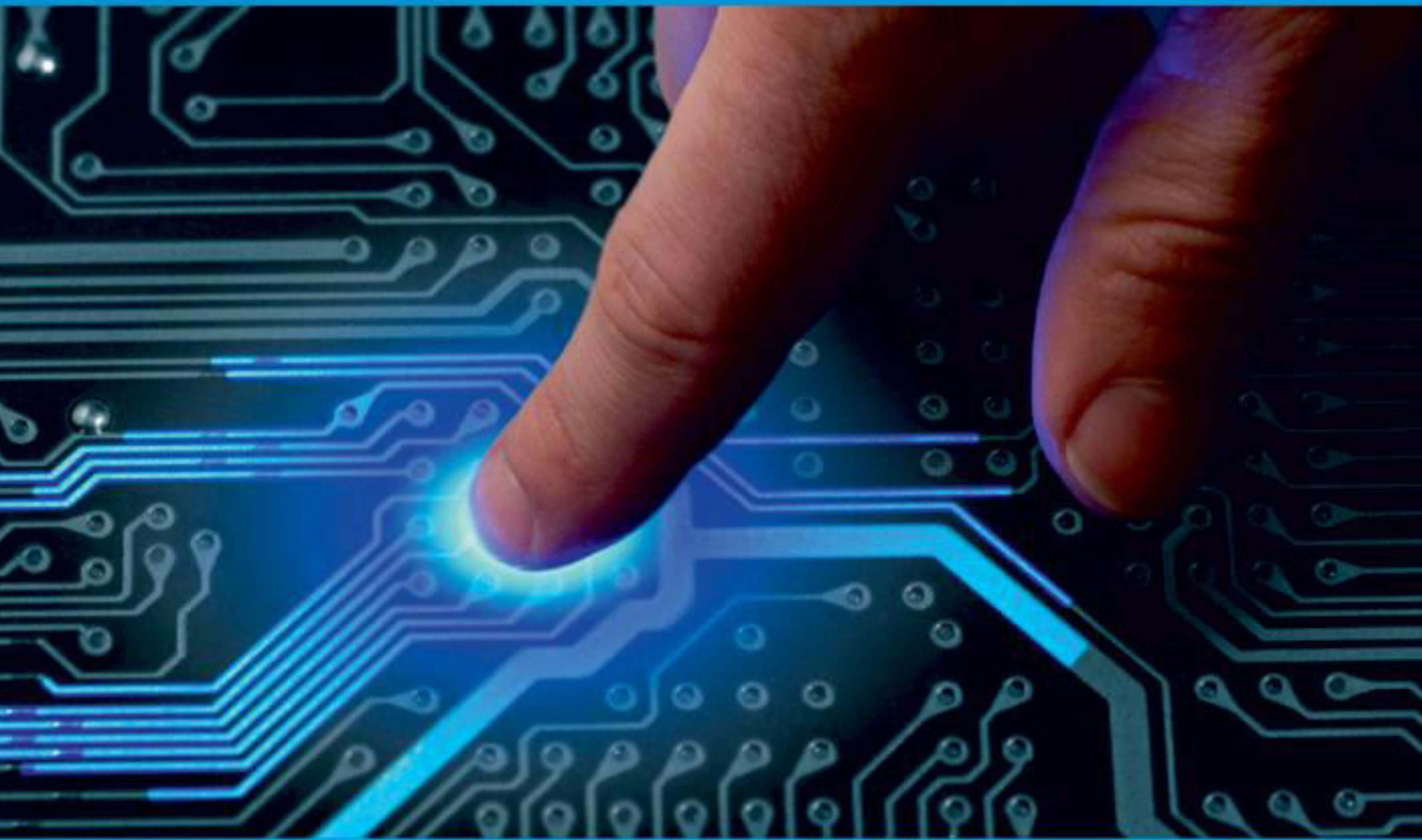

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Comparative Analysis of Solar Inverter Systems with respect to Indian Operating Environments

Vijaya Patil[#1], D.G Agrawal[*2]

Department of Electronics and Communication, Shri Sant Gadgebaba College of Engineering, Bhusawal, India[1]

Department of Electronics and Communication, Shri Sant Gadgebaba College of Engineering, Bhusawal, India[2]

ABSTRACT*:* This paper discusses the state of the art in the field of inverters being used in currently in solar power generation systems. Most of the works in the recent past have been dealing with the threw main inverter configurations i.e the Micro, String and Central. This review article discusses the principle working points of all the configurations and also the associated pros and cons with each of these systems.

KEYWORDS: Solar power harvesting, String inverter, Micro inverter, Inverter Efficiency

I. INTRODUCTION

Solar energy is being considered as the most pivotal block for addressing the energy needs of modern India. India has targets for solar PV of 100 GW under the National Solar Mission by next year. The capacity was found to be 28GW March 2019[1]. We know, Solar panels produce Direct Current which is unsuitable for common household appliances and cant be fed into the mains, and requires conversion to Alternating Current (AC). Herein comes the need of solar inverters for this inversion. They are also known as grid tied inverters. Since solar panels output Direct Current (DC) which is non compatible with common household appliances nor can be fed into the mains grid, the first requirement is to convert it to Alternating Current . The process is accomplished by solar inverters, which are also known as grid tied inverters. Normally grid connected PV systems employ one of these 3 systems namely Centralised, Multiple String Inverters, and micro inverter [2,3].

Central inverters are fairly large & used for supporting additional strings of solar panels. Instead of running strings directly to the inverter, they are joined together in a combiner so that the generated DC can be directed towards the middle inverter Such inverters need lesser connections, but need a pad as well as combiner box. Such inverters are suitable for huge installations through reliable production via arrays. The capacity of these inverters ranges from MWs to the hundreds of KWs with capacities of handling upto 500kW for each area[4,5]. Primary usage is not in homes but commercial installations & solar farms.

String inverters are most commonly used in home and commercial solar power systems. It consists of large box some distance away from the solar array. Based on the size of the installation, it can have multiple string inverter.
The micro inverter is appreciably small as compared to centralised and is attached to the PV module followed by connecting them in an array in parallel. It has the distinct advantage of converting DC to the grid synchronized AC, avoiding system islanding and providing better efficiencies[6]. Other pros are the removal of dc string cabling there by reducing installation costs and with better results of solar energy harvesting [7]. Micro inverters can be optimised for improved efficiencies resulting in decreased energy costs.

II. INVERTER TOPOLOGIES

For both home and commercial usage, nowadays string as well as micro inverter topologies are being employed. For string inverter, the PV module consists of series connections, which normally work at voltages in range of 400 to 1000. These in turn are then connected parellelly, using string diodes, reaching power levels of 10–250 kW [5].
The concept of the micro inverter is not a new one and has been there for a while.

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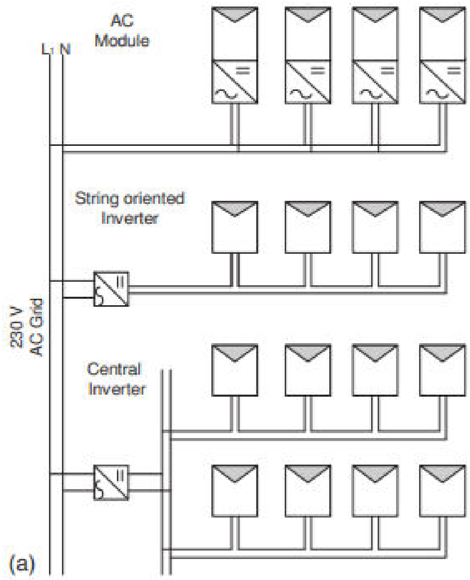
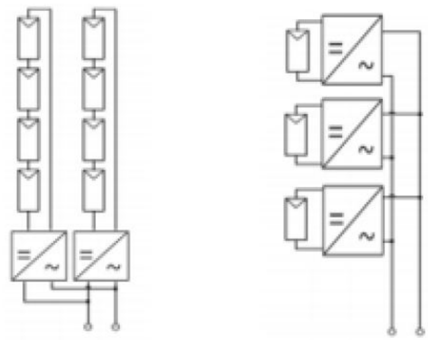


Fig 1 Central Inverter Topology



(a) (b)

Fig 2 (a) String. (b) Micro-inverter.

In 1991 first variants of the micro-inverter was introduced which performed inefficiently. It was more like a compact string inverter. Ascension Technology, a US based company developed the initial version. In 1994 , Sandia Labs tested the system and in 1993, Mastervolt introduced the first ever grid-tied micro inverter titled as the SunMaster 130S developed jointly by multinationals like Shell, Ecofys and also ECN. Some other versions like the The OK4E100E micro inverter were designed by OKE Services in 1995 and NKF Kabel promoting it to the European market. The reliability of the micro-inverter has been found to be very good for an electronic systems operating in constant heat and moisture. Some inverters like that from Emphase have a MTBF reaching upto 300 years with a NEMA rating of 6.[8]

But still the series connection, results in the inverter with the output of the array as per the least performing module in case of one module poor performance of any of the modules, due to mismatch losses [9]. One more problem that arises is the dependence of the entire system on few inverters. A string inverter claims to have a span of 25 years. [10].

Micro inverters have the distinct advantage of maintaining a robust and consistent flow of power even with shading on one or more of the panels. String of modules in case of a micro inverter array is connected parallely instead of it being in series as is the case in a conventional inverter. Because of the fact that the micro inverters service a solitary module, it offers the advantage of tracking and monitoring the power per module in real time. The array is monitored with conventional string inverters for checking the overall output of every string of module performance. If any module in a string malfunctions, the installer can find the single module that is affecting the string leading to the malfunctioning of the total output of the array. Hence with Micro inverters, detection of the bad module can be done remotely and almost instantaneously. String inverters always act as per the least efficient module in a string. For example if a particular module has more resistance than the rest of the modules in a string, then the entire string will

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perform less efficiently. Alterations in modules do not affect the end output of the array due to the fact that modules with micro inverters are independent contributors add independantly to the output power. Different types and different manufacturers' modules are used in strings of Micro-inverters. The only thing that needs to be taken care of while building a string for a conventional inverter is that each module needs to possess same electrical characteristics or should be of same make. Maximum power point tracking is also one of important parameters while judging the performance of the inverter. The way maximum power point tracking works is to create a resistance or load which then measure the current flowing from the array or from a single module as in the case of a microinverter. For string inverters, this resistance is in response to the amperage output of the aggregate of modules in the array. Different modules in the string may have differing mpp values hinting to the fact that some modules are not performing as they should thereby leading to loss of power [11,12]. Since each micro inverter contains a maximum power point tracker, each module performs to its maximum best

Table I summarizes the benefits and drawbacks of String and Micro inverter topology

TABLE I
COMPARISON OF STRING INVERTER & MICRO INVERTER

	String	**Microinverter**
Functionality	Modules in parallel by multiple strings and finally connected to the string inverter	Each module has one micro inverter for end conversion, Shading only affects individual modules.
Cost	Low	High
Shading performance	Poor	High
Module level monitoring	No	Yes
Mismatch losses	Yes	No
Electronic Assembly	Simple	Complex
Safety	Lesser than Micro Inverter	Safer than String topology, as uses only AC cabling without high voltage DC power

III. LITERATURE SURVEY

Recently PV technology has been an active area of research and lots of documented work has been published in recent times, especially case studies for demographically different places and under varied conditions of shading and other actor. The choice of an inverter affects the end energy production and the total cost of the system. In [13], the performance of central and string inverter are compared for a PV plant in Spain. In this case, the distributed system outperformed the one with centralized architecture. In contrast, the case of study presented in this work is a residential project of 5.1 kWp in Colombia, therefore the comparison is made between both types of inverters. In [14] the performance of an inverter with a transformer integrated and transformer less for an PV utility plant is compared. The works states a performance increases by 1.2% in the micro inverter with respect to the transformer integrated technology. A similar comparison has been done in [15], where the performance of string and microinverter are contrasted. This work tries to evaluate the performance of the micro inverter systems under varied shadowing situations. Comparative analysis shows that micro inverter systems present better performances under shadowed and partially shadowed conditions; however, an economic evaluation in which the Levelled Cost of Energy is contrasted between the inverter system topologies is still missing. [16] a givs a comparison of micro inverter and string inverter topologies for

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grid-tie residential photovoltaic system on economic as well as technical grounds. Initially, these topologies are described, presenting their benefits and drawbacks. Then, a 5.1 kWp system is modeled as a case of study. Two environments were used to analyse the topology performance, one under shadowed and another on partially or no unshadowed. [17] discusses Tabuchi make hybrid inverter which they state that it provides multiple energy savings and back-up functions through its state of the art software architecture and multi-string configuration. Results from real installation sites are provided and future technology trends in hybrid inverter are also discussed in this work.

[18] presents the design and analysis of a micro inverter making use of a single boost converter with Maximum Power Point Tracking feature (MPPT) and H bridge inverter along with a PI controller. The response of this system was documented for varied irradiation conditions

IV. PERFORMANCE INDEXES

Most importantly, inverter's overall efficiency is the most important performance metric that represents the amount of DC to AC power conversion. 100% efficiency is generally never achieved as input DC power is consumed by the inverter. The efficiency is altered by changing the utilized power and gradually it will increase when with more power consumption. It may vary from 50% at bottom ranges of utilized power going to over 90% at the rated power. Solar inverter efficiency is an area of active research and is being improved by incrementing operations, growing competition, and increasing the budget for inverter improvement. Photo Voltaic inverter efficiency is an extremely crucial factor that helps in reduction of the cost of the power for solar systems which is generally higher than those in prevalent systems. However, PV inverter cost is reducing relatively slowly as compared to PV panels, due to the fact that there is lower competition due to the higher obstacles in power electronics technology. Various standards are being used globally and different types of efficiencies are defined for solar inverters such as peak efficiency, CEC (California Energy Commission) efficiency, and European efficiency.[12],

A. Peak Efficiency

The peak efficiency illustrates the maximum efficiency at which the PV inverter can operate. It should be considered that the peak efficiency cannot be a reliable value since it normally happens 20-30% of the inverter rated power. Consequently, average efficiency is a more trustworthy metric.

B. CEC Weighted Efficiency

Since peak efficiency is not the industry standard in comparing the inverters in the actual operating environment, weighted efficiencies are being used. In this , Efficiency at different power levels is measured and this average value gives a more accurate representation than the peak efficiency. One of the suggested weighted efficiency formulas that is being used is prescribed by the California Energy Commission (CEC). CEC efficiency is calculated by averaging the value of DC to AC conversion efficiencies at six pre decided outputs ranging between 10- 100% of the rated power.

C. European Weighted Efficiency

Since PV systems are located in a wide range of solar irradiance in real applications, in order to consider the different levels of efficiency at different levels of input power, a different factor is regularly utilized. This is named European efficiency. Similar to CEC, the weighting factors are slightly varied.

However, majority of these efficiency computation mechanisms are as per inverter European efficiencies or at California, thus they don't qualify as an accurate and suitable standard to compute the conversion efficiency of the inverters in different locations. Some works have been done with respect to refining calculation of efficiencies keeping in mind the Indian demographic locations. The work by Anish et.al.[19] analysed in detail efficiencies for tropical environments in Chennai, India taking into account the effects of varying irradiation. A similar representation has been given on 3 phase voltage source inverter by Jayakumar et.al [20], and it can be installed at all places with lesser costs and losses as compared to conventional systems. Tania Tony et.al [21] discussed the distributed generation mechanism to handle the energy crisis in India. [1] worked on weighing coefficients for calculating PV inverter efficiency for specific climate zones in India which can simplify choosing location based inverters for higher efficiency as well as increased revenue

V. CONCLUSIONS

In general, as per the case studies listed here, it has been observed that the values of LCOE achieved with micro inverter are slightly lower than using the string inverter topology. Also, the micro inverter topology significantly improves upon the performance ratio in shadowed and unshadowed environments.

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Hence we conclude that, the use of micro inverter topologies is preferable for residential systems despite the fact that such systems need high initial monetary input. Other benefits of micro inverters include (1) Comparatively lower installation and maintenance costs (2) monitoring system per module, (3) no minimum power constraints and (4) lower DC voltage levels, that help prevent fire electrical incidents. Also amended weighing coefficient factors as per Indian demographic locations need to be used for estimation of PV inverter's weighted average efficiency for respective climatic zones. This will help Indian project developers for selection of a profitable inverter based on performance of inverters. Also, it will help in more accurate prediction of yearly output of inverter.

REFERENCES

[1] Akshaya Harish, Aravindakshan Ramanan, Prasun Kumar Das, Dr.K.Balaraman *Formulation of performance of inverters for solar photovoltaic power plants – I ndian case study*, 2nd Int'l Conference on Large-Scale Grid Integration of Renewable Energy in India| New Delhi, India | 4-6 Sep 2019.

[2] L. Hassaine, E. OLias, J. Quintero, and V. Salas, "Overview of power inverter topologies and control structures for grid connected photovoltaic systems," Renew. Sustain. Energy Rev., vol. 30, pp. 796–807, 2014..

[3] M. Rashid. Power Electronics Handbook. Elsevier Science, 2011. ISBN 9780123820372.

[4] N. Foureaux, A. Machado, É. Silva, I. Pires, J. Brito and Braz Cardoso F., "Central inverter topology issues in large-scale photovoltaic power plants: Shading and system losses," 2015 IEEE 42nd Photovoltaic Specialist Conference (PVSC), 2015, pp. 1-6, doi: 10.1109/PVSC.2015.7355828..

[5] S. K. Chattopadhyay and C. Chakraborty, "Photovoltaic central inverters: Performance evaluation and comparative assessment," IECON 2017 - 43rd Annual Conference of the IEEE Industrial Electronics Society, 2017, pp. 6419-6424, doi: 10.1109/IECON.2017.8217118

[6] D. M. Scholten, N. Ertugrul and W. L. Soong, "Micro-inverters in small scale PV systems: A review and future directions," 2013 Australasian Universities Power Engineering Conference (AUPEC), 2013, pp. 1-6, doi: 10.1109/AUPEC.2013.6725465.

[7] D. Pal, H. Koniki and P. Bajpai, "Central and micro inverters for solar photovoltaic integration in AC grid," 2016 National Power Systems Conference (NPSC), 2016, pp. 1-6, doi: 10.1109/NPSC.2016.7858972.

[8] Enphase, Reliability of Enphase Micro-inverters,. Accessed on: Aug 13, 2021. [Online]. Available: http://www2.enphase.com/wp-uploads/enphase.com/2011/03/Enphase_WhitePaper_Reliability_of_Enphase_Micro-inverters.pdf..

[9] Ahmed Al Mansur , Md. Ruhul Amin, Kazi Khairul Islam, "Performance Comparison of Mismatch Power Loss Minimization Techniques in Series-Parallel PV Array Configurations," Energies 2019, 12, 874; doi:10.3390/en12050874.

[10] Harb, Souhib & Kedia, Mohit & Zhang, Haiyu & Balog, Robert. (2013). Microinverter and string inverter grid-connected photovoltaic system — A comprehensive study. Conference Record of the IEEE Photovoltaic Specialists Conference. 2885-2890. 10.1109/PVSC.2013.6745072..

[11] J. Yuan, F. Blaabjerg, Y. Yang, A. Sangwongwanich and Y. Shen, "An Overview of Photovoltaic Microinverters: Topology, Efficiency, and Reliability," 2019 IEEE 13th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG), 2019, pp. 1-6, doi: 10.1109/CPE.2019.8862334

[12] .A. M. Sadati, S. Krauter and J. Bendfeld, "Comparison of micro inverters based on practical analysis," 2015 5th International Youth Conference on Energy (IYCE), 2015, pp. 1-6, doi: 10.1109/IYCE.2015.7180817.

[13] M. Díez-Mediavilla, M. I. Dieste-Velasco, M. C. Rodríguez-Amigo, T. García-Calderón, and C. Alonso-Tristán, "Performance of gridtied PV facilities based on real data in Spain: Central inverter versus string system," Energy Convers. Manag., vol. 86, pp. 1128–1133, 2014

[14] M. Díez-Mediavilla, M. I. Dieste-Velasco, M. C. Rodríguez-Amigo,T. García-Calderón, and C. Alonso-Tristán, "Performance of gridtie PV facilities: A case study based on real data," Energy Convers.Manag., vol. 76, pp. 893–898, 2013.

[15] F. Famoso, R. Lanzafame, S. Maenza, and P. F. Scandura, "Performance Comparison between Micro-inverter and String inverter Photovoltaic Systems," Energy Procedia, vol. 81, pp. 526–539, Dec. 2015.

[16] O. A. Arráez-Cancelliere, N. Muñoz-Galeano and J. M. Lopez-Lezama, "Performance and economical comparison between micro-inverter and string inverter in a 5, 1 kWp residential PV-system in Colombia," 2017 IEEE Workshop on Power Electronics and Power Quality Applications (PEPQA), 2017, pp. 1-5, doi: 10.1109/PEPQA.2017.7981678.

[17] M. T. A. Khan, T. Tanaka, B. Tan, R. Dagstanyan and J. Borland, "Hybrid String Inverter with Energy Storage for Grid Independent Power System," 2018 IEEE 7th World Conference on Photovoltaic Energy Conversion (WCPEC) (A Joint Conference of 45th IEEE PVSC, 28th PVSEC & 34th EU PVSEC), 2018, pp. 0573-0578, doi: 10.1109/PVSC.2018.8547655.

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|| Volume 9, Issue 8, August 2021 ||

| DOI: 10.15680/IJIRCCE.2021.0908038 |

[18] E. Kabalci, A. Boyar and Y. Kabalci, "Design and analysis of a micro inverter for PV plants," 2017 9th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), 2017, pp. 1-6, doi: 10.1109/ECAI.2017.8166459

[19] A. Kalathil and H. Krishnamurthy, "Quantification of solar inverter efficiency for Indian tropical climatic conditions," 2014 IEEE Region 10 Humanitarian Technology Conference (R10 HTC), 2014, pp. 14-18, doi: 10.1109/R10-HTC.2014.7026316.

[20] M. Jayakumar, Vanitha, V., Jaisuriya, V., Karthikeyan, M., Daniel, G., and Vignesh, T., “Maximum power point tracking of a solar PV array using single stage three phase inverter”, International Journal of Engineering and Technology(UAE), vol. 7, pp. 97-100, 2018

[21] Tania Tony, Sivraj P. and Sasi K.K., “Net Energy Meter with Appliance Control and Bidirectional Communication Capability”, 2016 Intl. Conference on Advances in Computing, Communications and Informatics (ICACCI), Sept. 21-24, 2016, Jaipur, India

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