ISSN No:-2456-2165

Modelling and Scheduling of Residential Grid-Connected Solar Cell-Based Photovoltaic System for Demand

[1]Monty Kumar
Electrical Engineer,
Guru Kashi University, Punjab, India
Mk350480@gmail.com

[2]Dr. Gurpreet Kaur
HOD Electrical Engineer
Guru Kashi University
Punjab, India

Abstract:- Due to the many benefits that come along with using photovoltaic (PV) systems, they are now in the driver's seat when it comes to using solar power as a renewable energy source (RES). This trend is becoming more prevalent, particularly in grid-connected applications, as a direct result of the many advantages brought about by the use of RES inside distributed generation (DG) systems. This new scenario makes it necessary to have an efficient tool for evaluating photovoltaic (PV) systems that are connected to the grid. This thesis focuses on addressing load fluctuation challenges in residential environments by developing an optimization framework for scheduling elastic residential appliances and integrating solar PV systems. The objective is to flatten the load profile and enable effective demand response implementation in smart grid systems. The proposed methodology utilizes the Particle Swarm Optimization (PSO) algorithm to optimize the scheduling of appliances and the utilization of solar PV energy. The thesis provides an introduction to the problem, outlines the methodology, presents the obtained results, and evaluates the effectiveness of the scheduling approach in load curve flattening.

Keywords:- *PSO Particle Swarm Optimization, DG Distributed Generation, PV Photo Voltaic*

I. INTRODUCTION

The worldwide depletion of fossil fuel reserves and the accompanying rise in pollution levels have exerted a powerful impetus over the last several decades toward the development of renewable energy technologies (RES). Improving energy supply structures based mostly on clean and renewable resources is necessary because of the growing need for sustainable energy systems to progressively replace conventional ones. In the realm of renewable energy sources (RES), photovoltaic (PV) production is now rising in prominence owing to its unique benefits, including its ease of allocation, high reliability, lack of fuel expense, minimal maintenance, and lack of noise and wear due to the absence of moving components. In addition, solar power is a renewable, sustainable, and non-depletable energy option. Along with these considerations, the ever-falling costs of solar modules are a major cause for optimism. Solar cell efficiency growth, manufacturing innovation, and cost reductions at scale. As PV systems continue to improve in efficiency and cost-effectiveness, the most popular use for them is no longer as a standalone power source as it is now: grid integration of renewable energy source (RES) applications. The many advantages of using RES in distributed (sometimes dispersed, embedded, or decentralised) generation (DG) power systems are increasing this trend. Among these benefits is the fact that grid-connected PV systems are more likely to be adopted commercially as a result of advantageous incentives offered in many countries. In order to make an informed decision about whether or not to integrate this technology into the electric utility grid, it is necessary to have access to high-quality designing tools and a method to accurately predict the dynamic performance of three-phase grid-connected PV systems under different operating conditions. The dynamic performance of the power conditioning system (PCS) needed to transform the energy generated into usable electricity and to satisfy requirements for power grid connectivity must be determined, in addition to the current-voltage (I-V) characteristics of PV modules or arrays. While global demand for electricity rises, the popularity of photovoltaic power fed into the utility system grows. Germany and Japan have the world's greatest installed capacities, contributing to the exponential growth. Provision without the restriction of supply of energy the main benefits of these systems are their low environmental impact compared to conventional energy sources like oil and natural gas, while the main negatives are their low efficiency and unpredictability. And when a PV system is tied to the grid, transmission system operators are enforcing strict regulations. Power system reliability and power quality are only two examples of the many essential requirements. Large amounts of time and energy are spent studying how to better regulate these systems so that they behave more effectively. 12 The increasing demand for electricity and the integration of renewable energy sources pose significant challenges for maintaining a stable and reliable power grid. Load fluctuations, especially in residential areas, can strain the grid infrastructure and lead to inefficiencies in energy generation and distribution. To address these challenges, demand response strategies and optimization techniques have gained attention in the context of smart grid systems. This thesis focuses on the optimization of scheduling elastic residential appliances, including the integration of solar photovoltaic (PV) systems, to flatten the load profile and enable effective demand response implementation in smart grids. By strategically scheduling the operation of appliances and leveraging solar PV generation, the objective is to achieve a more balanced and stable load distribution, reduce peak loads, and enhance the utilization of renewable energy.

II. PROBLEM STATEMENT

The problem addressed in this research is the load fluctuation challenge in residential environments and the need for load profile flattening to enable effective demand response implementation in smart grid systems. Load fluctuations, caused by the operation of elastic residential appliances, can strain the power grid infrastructure, lead to inefficiencies in energy generation and distribution, and result in increased costs and decreased grid reliability. Furthermore, the integration of renewable energy sources, such as solar PV systems, introduces additional complexities in balancing energy generation and consumption. The existing approaches for load management and demand response often lack optimization techniques to effectively schedule the operation of elastic appliances and integrate renewable energy sources. Traditional methods do not fully exploit the flexibility of appliance scheduling or the potential of renewable energy generation. As a result, the load profile remains uneven, with significant peak loads and inefficient utilization of available resources. Therefore, the problem addressed in this research is to develop an optimization framework that leverages the Particle Swarm Optimization (PSO) algorithm to schedule the operation of elastic residential appliances, including the integration of solar PV systems, to achieve load profile flattening. The objective is to minimize load fluctuations, reduce peak loads, and maximize the utilization of renewable energy sources, while respecting appliance flexibility, user preferences, and system-level constraints. The proposed framework aims to provide an efficient and practical solution for load management, enabling effective demand response participation and promoting a more sustainable and resilient smart grid infrastructure. By addressing this problem, the research aims to contribute to the optimization of residential energy consumption, enhance grid stability and reliability, reduce electricity costs, promote 19 energy efficiency, and facilitate the integration of renewable energy sources in smart grid systems.

III. OBJECTIVES

- The primary objective of this research is to develop an optimization framework for scheduling elastic residential appliances, including the integration of solar PV systems, to achieve load profile flattening and enable effective demand response implementation in smart grid systems. Specifically, the objectives are:
- Optimize the scheduling of elastic residential appliances: Develop an algorithm, based on Particle Swarm Optimization (PSO), to determine the optimal scheduling of elastic appliances, taking into account appliance flexibility, user preferences, and system-level constraints.
- Integrate solar PV generation: Incorporate solar PV generation into the scheduling optimization framework, considering the availability of solar energy and its contribution to load profile flattening.

IV. IMPLEMENTATION DETAILS

Optimization Framework Implementation: Develop the software implementation of the optimization framework using a programming language such as Python. Implement the PSO algorithm, the objective function, and the constraints.

Here are the equations for Particle Swarm Optimization (PSO) and the constraints for the optimization problem of scheduling elastic residential appliances, including solar PV integration, for load profile flattening:

Equations for PSO: Particle Position Update Equation:

For each particle i at iteration t:

$$x\_i(t+1) = x\_i(t) + v\_i(t+1)$$

where $x\_i(t)$ is the current position of particle i, and $v\_i(t+1)$ is the velocity of particle i at iteration t+1.

Particle Velocity Update Equation:

For each particle i at iteration t:

$$v\_i(t+1) = w * v\_i(t) + c1 * rand1 * (pbest\_i(t) - x\_i(t)) + c2 * rand2 * (gbest(t) - x\_i(t))$$

where $v\_i(t)$ is the current velocity of particle i, w is the inertia weight, c1 and c2 are the cognitive and social parameters, rand1 and rand2 are random numbers between 0 and 1, $pbest\_i(t)$ is the best position of particle i so far, and gbest(t) is the global best position among all particles at iteration t.

Constraints for Load Scheduling Optimization: Appliance Operational Constraints: Each appliance must operate within its specified time window and duration constraints. The power consumption of each appliance must be within its power rating limits. The starting time and ending time of each appliance must satisfy the overall scheduling requirements.

Energy Balance Constraint: The total energy consumption of all scheduled appliances, combined with the solar PV generation, must balance with the total energy demand over the scheduling horizon. It can be represented as:

$$\Sigma(P\_appliance\_i(t) + P\_PV(t)) = \Sigma D(t)$$

where $P\_appliance\_i(t)$ represents the power consumption of appliance i at time t, $P\_PV(t)$ represents the solar PV generation at time t, and D(t) represents the total energy demand at time t.

Solar PV Integration Constraint: The scheduling algorithm must consider the availability of solar PV energy and allocate it to appliances accordingly. This can be represented as:

P_appliance_i(t) ≤ min(P_appliance_i(max), P_PV(t))

where P_appliance_i(max) represents the maximum power consumption of appliance i, ensuring that the appliance's power requirement does not exceed the available solar PV energy.

System-Level Constraints: The power demand must not exceed the capacity of the grid connection. The voltage levels and current limits must be within acceptable ranges. Any other specific constraints related to the grid infrastructure, safety regulations, or user preferences. These equations and constraints provide a foundation for the PSO-based optimization framework for load profile flattening and solar PV integration in scheduling elastic residential appliances. However, it is important to note that the actual implementation may involve additional considerations and customization based on the specific characteristics of the appliances, grid infrastructure, and user requirements. Integration with Data and Models: Integrate the collected data, appliance models, solar PV models, and optimization framework to create a cohesive system. Performance Evaluation: Evaluate the performance of the optimization framework using appropriate metrics such as load profile graphs, peak load reduction percentages, renewable energy utilization rates, and cost savings.

V. RESULT

- Description of test system and other input parameters the impact of DR on the optimal accommodation of renewable based DGs in distribution system is studied on 33-bus radial distribution system. The single line diagram of this test system is represented in Figure 1 and other relevant data can be referred to. This system has nominal active and reactive load of 3.715 MW and 2.300 MVar respectively. In order to get the load profile for one day of each node, nominal demand of nodes is multiplied by load factor which is shown in Figure. The per-unit power from PV and WT for one day is obtained from and is also shown in Figure. DRrate, max loc dg and max cap dg are taken as 20%, 3 and 3.6 MW respectively.

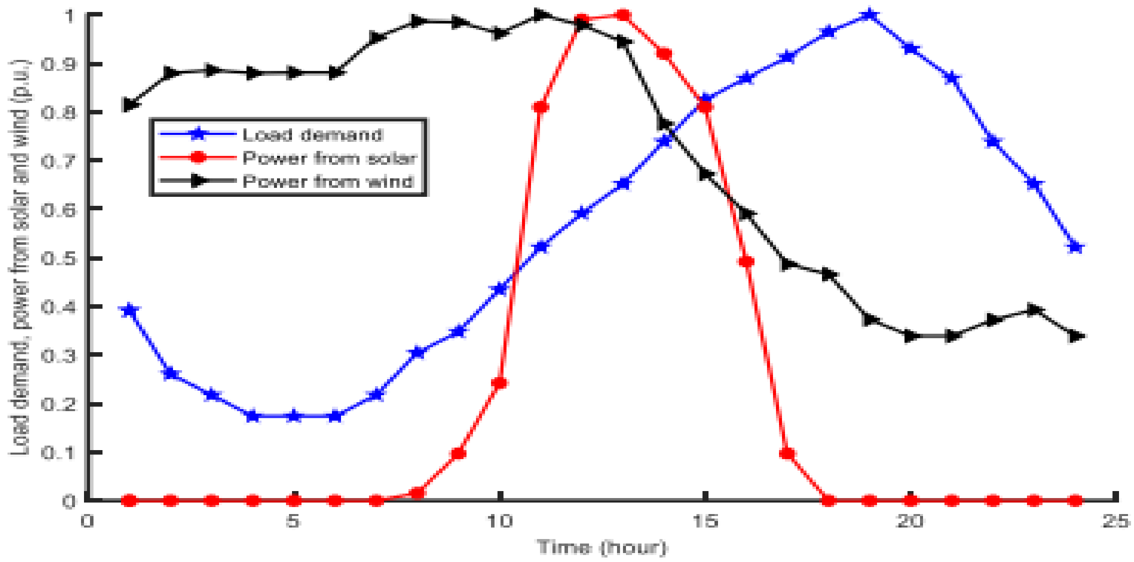

Fig 1 One Day Profile of Load Demand, Power from Solar and Wind in per Unit

- Case studies in this study, three situations are taken into consideration for a thorough investigation. Only wind power production is allotted in instance 1. In example 2, only PV generation is allotted, but case 3 allows for the integration of both wind and PV DGs into the distribution system. There are two described possibilities for every one of the three instances. There is no DR in case 1. Therefore, in scenario 1, there is no shifting of loads. In scenario 2, accommodating DGs based on renewable energy sources is combined with scheduling of flexible loads. In addition to these scenarios, a basic case—a distribution system without either DR or RE—is also investigated for comparison's sake. On the basis of energy losses, minimum voltage obtained at every time of day and at any node, voltage variation, penetration of renewable DG, as well as the ideal placement and size, and substation peak demand, respectively, results of various scenarios are compared. Results of case studies at bus 18 (19:00 hours), the system's network loss in the basic scenario is 1860.40 kW with a minimum voltage of 0.9131 p.u. Voltage variance for the whole network is 22.43 p.u. per day, while the substation's peak demand is 3971.70 kW.

ISSN No:-2456-2165

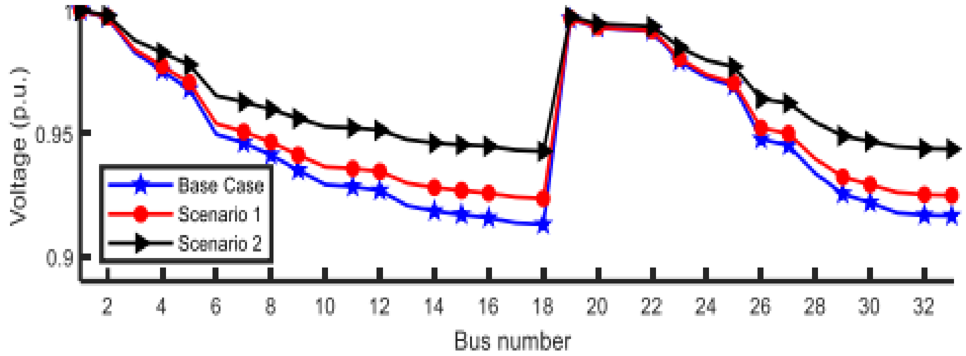

Fig 2 (a) Minimum Node Voltage

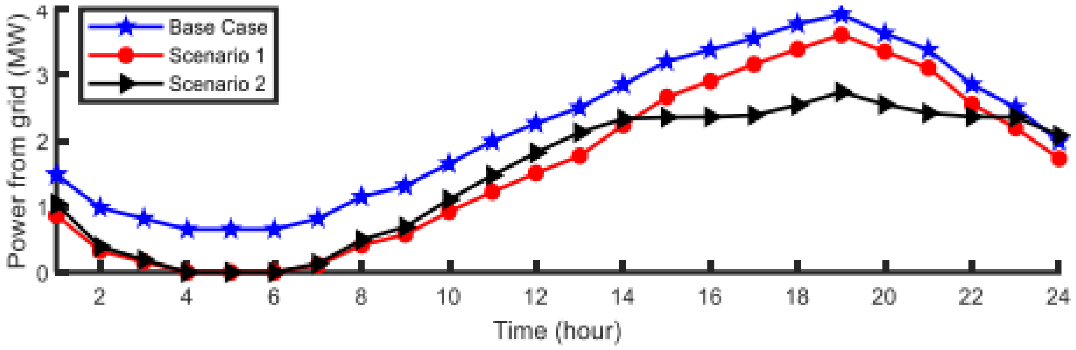

Fig 3 (b) Power Taken from Grid

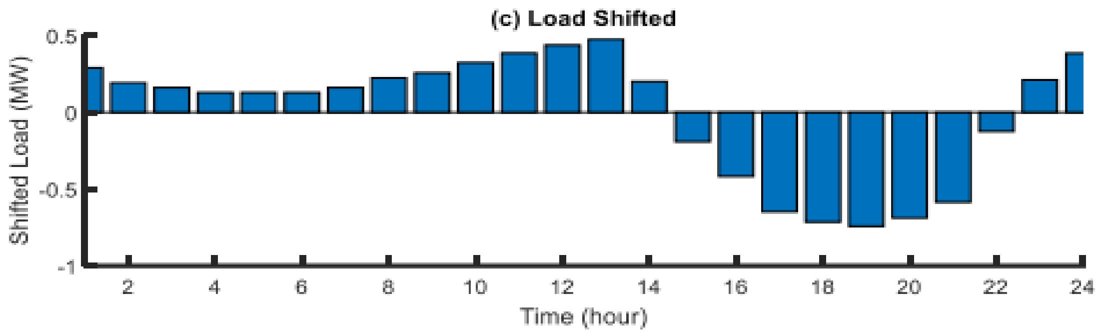

Fig 4 (c) Load Shifted.

Minimum node voltage profile, power taken from substation and load demand shifted for case 1 In instance 2, the PV is integrated into the distribution system in the best possible way. The simulation results for both situations are reported in Table 2, and Figure 4 displays the lowest node voltage, grid power used, and load transferred over the course of a day. It is discovered that in scenarios 1 and 2, the energy losses are decreased by 20.24% and 35.17%, respectively, in comparison to the base case. In contrast to scenario 1, the best position of the PV in this instance stays the same both before and after DR. In addition to the system's technical characteristics being improved, DR is shown to enhance PV penetration by 12.27%. The minimum node voltages in the base case and scenario 1 remain the same, as can be shown in Figure 4(a). This is due to the fact that solar power is not available when the network is at its busiest. Peak demand (3.715 MW), in both the base case and scenario 1, occurs at 19:00. The minimum node voltage has increased from 0.9131 p.u. to 0.9316 p.u. in scenario-2 compared to scenario-1 because some load demand is pushed out during peak load hours (16:00 to 23:00), as seen in Figure 4(c). Additionally, Figure 4(a) shows how the minimum voltage of all nodes improved when PV was accommodated optimally in the presence of DR. Due to the availability of electricity from PV between the hours of 9:00 to 17:00, scenario 1's power consumption from the grid is lower than base case. In scenario 1, the load demand is entirely satisfied by the grid during non-peak hours. As a result, the grid power profile for the base case and scenario 1 overlap. In scenario 2, some load is also moved in from 01:00 to 10:00 in order to reduce energy losses, which raises the amount of imported electricity from the grid in comparison to scenario 1. Even if some load is transferred into scenario 2 during the period from 11:00 to 13:00, the amount of electricity used from the grid is the same in both situations. It took place as a consequence of greater PV penetration in scenario 2 as a result of extra PV electricity being added to meet the flexible load demand during these hours. Additionally, load demand is pushed out during peak load hours to maximize energy savings, which lowers the amount of grid power required in scenario 2. The substation peak demand in scenario 2 is 873.38 kW lower than the base case peak demand.

Table 1 Simulation Results for Case 2

	Network Losses (kW)	Minimum voltage (p.u.)	Voltage deviation (p.u.)	Penetration of RE (%)	Location (size (kW))
Scenario-1	1483.80	0.9131	17.72	60.50	14(612.50), 24(778.41), 30(856.25)
Scenario-2	1206.10	0.9316	16.73	72.76	14(722.80), 24(979.40), 30(1000.87)

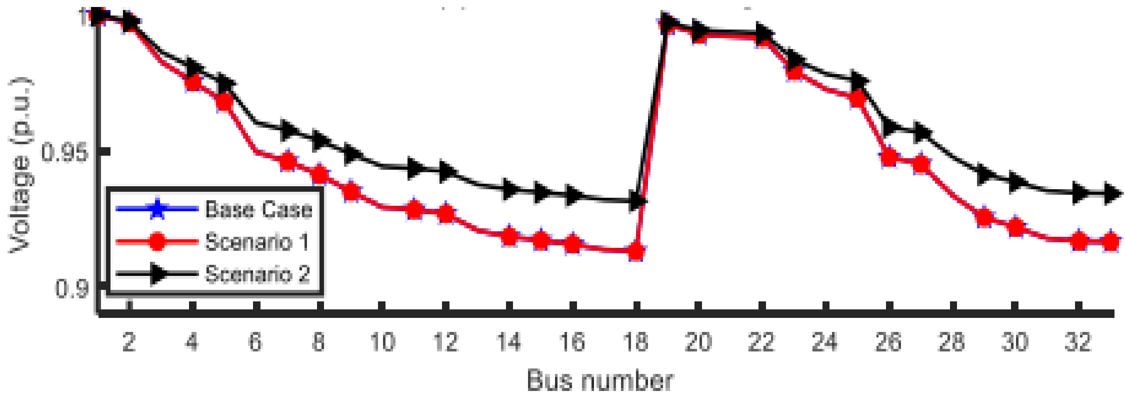

Fig 5 (a) Minimum Node Voltage

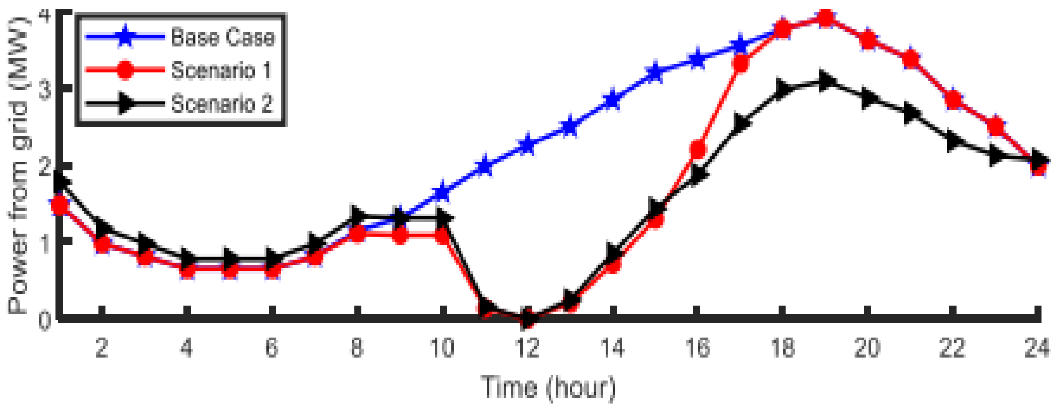

Fig 6 (b) Power Taken from Grid

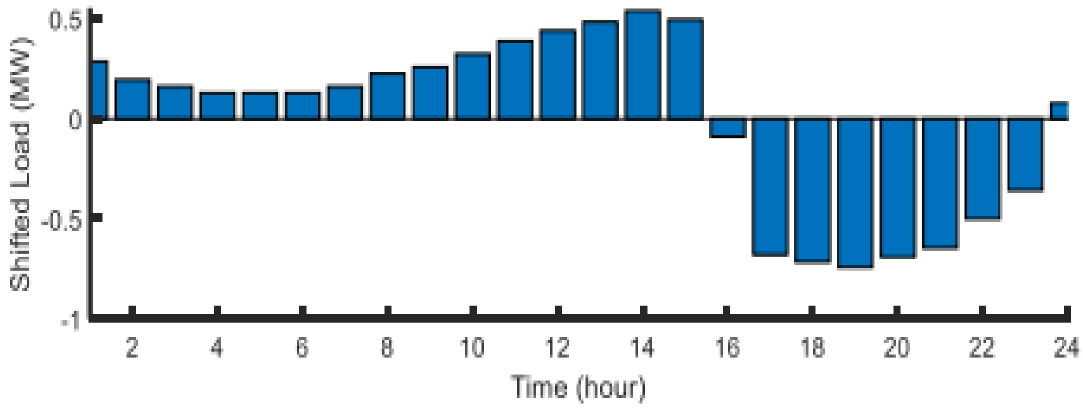

Fig 7 (c) Load Shifted

Minimum node voltage profile, power taken from substation and load demand shifted for case 2

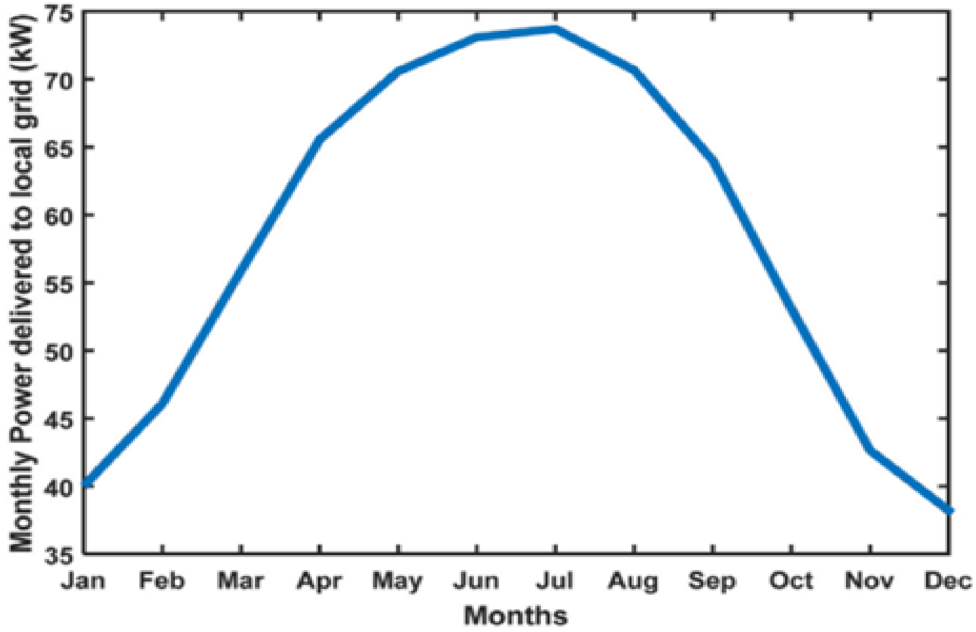

Fig 8 Power Delivered from PV System to the 220 V Local Grid.

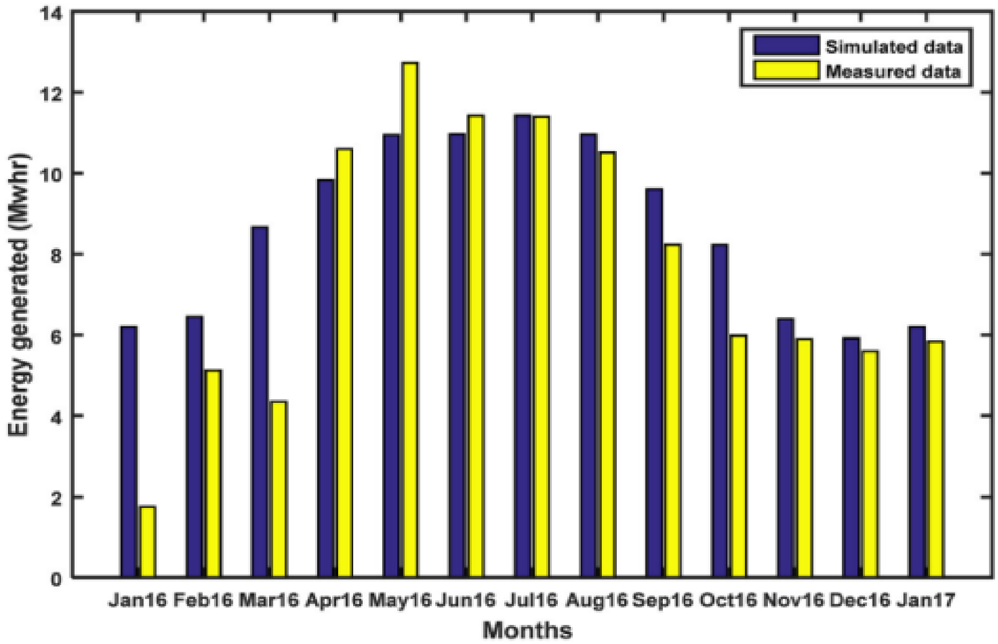

Fig 9 Simulated and Measured Energy Generated Sfrom PV System Connected to the Local Grid.

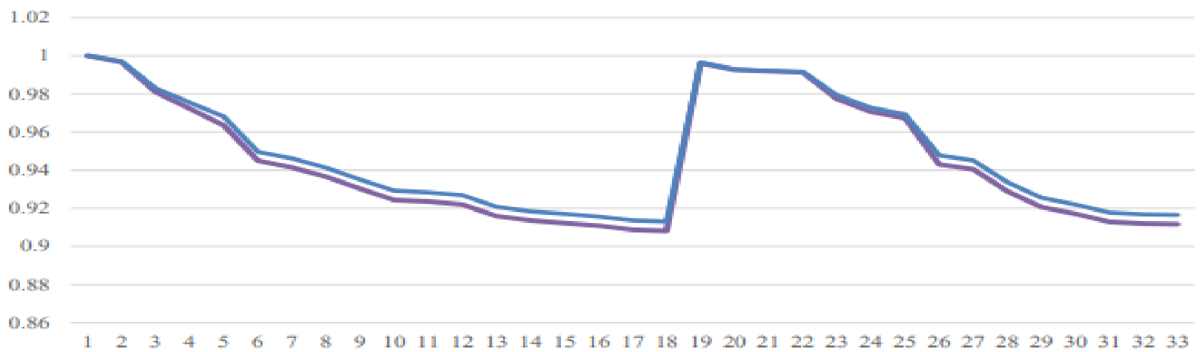

Fig 10 Series1 Represents Minimum Voltage without Solar Cell and Series 2 Represents Minimum Voltage with Solar Cell in the Distribution System.

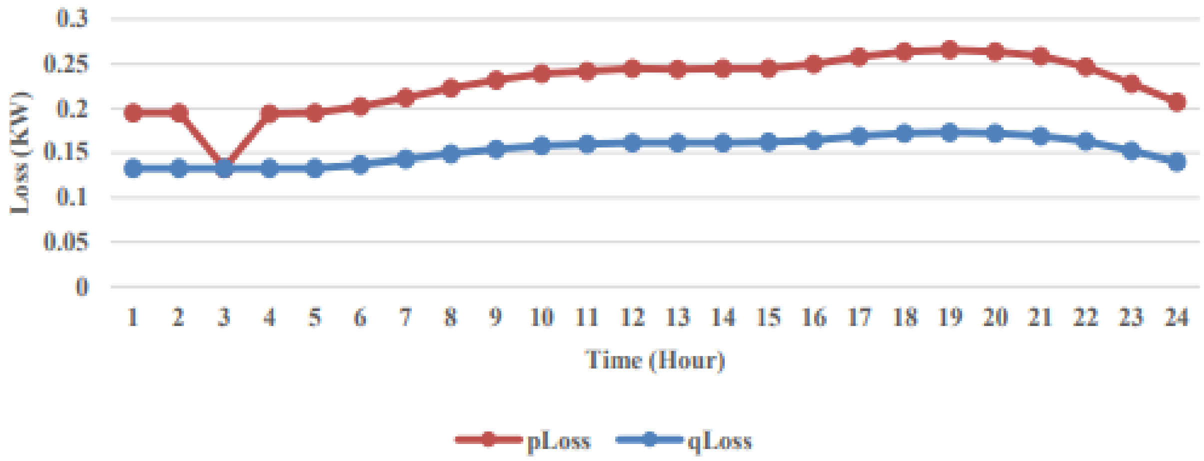

Fig 11 pLoss and qLoss in the System.

Table 2 Power Loss and Minimum Voltage for Different Cases

System Configuration	Min Voltage (p.u.)	Max PLoss (kW)
Without Solar cell in the system	0.9388	256
With Solar cell	0.9059	311

VI. CONCLUSION

A modelling and control strategy for a solar system that is linked to the grid is discussed in this study. It is permissible to use a causal informational graph approach and its inherent properties in order to identify all basic models and to compute both the PV-side and the grid side controllers. In this manner, a controller is used to extract the maximum amount of power from the solar cells, a current regulator and a dc link voltage regulator are used to transmit the power from the photovoltaic cells, and an output inverter is synchronized with the grid using all of these components. The performances of the grid-connected photovoltaic are shown via the use of a simulated model and the results acquired under typical operating settings. The impact of solar cell on the distribution system is also explained in terms of voltage and losses.

REFERENCES

[1]. J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galván, R. C. PortilloGuisado, M. A. Martín-Prats, J. I. León, N. Moreno-Alfonso, "Power electronic systems for the grid integration of renewable energy sources: a survey," IEEE Trans. Industrial Electronics, vol. 53, no. 4, pp.1002-1016, 2006.

[2]. W. El-Khattam, M. M. A. Salama, "Distributed generation technologies: definitions and benefits," Electric Power Systems Research, vol. 71, pp. 119-128, 2004.

[3]. A. Poullikkas, "Implementation of distributed generation technologies in isolated power," Renewable and Sustainable Energy Reviews, vol. 11, pp. 30-56, 2007.

[4]. The MathWorks Inc. SimPowerSystems for use with Simulink 7: User's Guide, Natick, MA, 2008.

[5]. T. Ackermann, G. Anderson, L. Söder "Distributed generation: a definition," Electric Power Systems Research, vol. 57, pp. 195-204, 2001.

[6]. S. W. Angrist, Direct Energy Conversion, second ed. Boston: Allyn and Bacon, 1971.

[7]. J. A. Duffie, W. A. Beckman, Solar Engineering of Thermal Processes, second ed. New York: John Wiley & Sons Inc, 1991.

[8]. J. Nelson, The Physics of Solar Cells. London: Imperial College Press, 2003.

[9]. D. L. King, J. A. Kratochvil, W. E. Boyson, W. I. Bower, "Field experience with a new performance characterization procedure for photovoltaic arrays," Proc. 2nd World Conf on Photovoltaic Solar Energy Conversion, vol. 1, pp. 6-10, 1998.

[10]. C. D. Schauder and H. Mehta, "Vector analysis and control of advanced static var compensators," IEE Proceedings-C, vol. 140, no. 4, pp. 299- 306, 1993.