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Voltage control of solar battery system integration in the distribution network

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ABSTRACT: When connecting a solar power (PV) systemto the distribution grid, it can cause a significant change in voltage at the connection point.If there is no controller to keep the voltage at the PV system connection point within allowable limits, disconnection may occur of the PV system out of the grid. Therefore, this article focuses onresearching local voltage control algorithms based on self-regulation voltage regulation of the PV system. This adjustment uses local information, allowing the PV system to be easily connectedand reduce connection costs, helping to increase solar penetration into the electricity system. This voltage regulatornot only controls the voltage at the connection point but can be applied to every point on the grid. Results of research by simulationMatlab-Simulink has confirmed its effectiveness for distribution grids taking into account the connection of different PV systems.

KEYWORDS: Solar power system; automatically adjust voltage; netdistribution.

I. INTRODUCTION

Future energy sources are facing a big challenge. The world's energy consumption todayincreases (about 2% per year) and most of the world's energy production is secured by fossil sources, so energy will become scarce and expensive. Besides, the consumption of fossil energy sources will lead to climate change, greenhouse effect due to CO_2 emissions, environmental pollution, etc.

In that context, renewable energy is increasingly asserting its position and importance compared to other energy sourcestraditional resources such as coal, gas, oil and nuclear. Continuous development of the energy market renewable energy has sparked hope in the birth of a new era - the era of renewable energy.

Among renewable energy sources, solar photovoltaic energy is a promising source. In context, the current economic situation is very favorable for the development of solar photovoltaic systems (science and technology development, price subsidy policies, tax incentives, capital subsidies, technical support,...) , the number of requests to connect PV systems is increasing exponentially around the world, especially for roof-mounted solar power models.

Connecting a solar power (PV) system will cause voltage changes on the grid due to changes in active and reactive power flows in the grid. In general, the voltage will increase at connection points and exposed wire points, which will lead to changes in voltage at other points on the grid. Depending on the level and the (intermittent) fluctuations, the energy contribution of PV systems to the distribution network can cause significant variations of the voltage at the point of connection [4, 5]. Especially leading to overvoltage at the internal connection point. In case of part load, the penetration level of solar power is high. If there is no regulator to maintain the PV system voltage within acceptable limits, it can cause disconnection from the grid.

This article presents the construction of a local voltage controller based on automatically and adaptively adjusting the voltage of the solar power system. Building this voltage regulator aims to increase the penetration of solar energy into the power system, increasing the efficiency and flexibility of connecting the PV system to the grid.

II. VOLTAGE CONTROLLER FOR THE SOLAR POWER SYSTEM

The inverter of a solar power system can operate with different control algorithms depending on its operating mode [2, 6, 7, 8, 9]. One of three types of reactive power regulation schemes can be applied to grid-connected inverters: either active and reactive power control (P/Q control), or system control. power number (P/PF control), or active power and voltage control (P/V control). The voltage/frequency control (V/F control) model is

commonly used for grid-connected inverters.
With the P/Q control scheme, the control algorithm is to regulate the injected power flow, by the distributed source, at the connection point. The purpose of the controller is to keep the active power and reactive powerinjected at the connection point constant and equal to the set values of P_{ref} and Q_{ref}. In fact, the active power Pref is determined by the MPPT algorithm and the reactive power Q_{ref} is 0. Similarly, for the power factor control scheme (P/PF control), the active power and The power factor is kept at the set value, by changing the reactive power the power factor is kept constant.

For the voltage/frequency control (V/f control) model, the voltage and frequency are held at the V_{ref} and fref settings.Active power and reactive power are regulatedcontrol to keep frequency and voltage constant. Change work effective power to adjust frequency and change capacity reactance to control voltage.

P/Q control diagram

The PV system is simulated using a current source and operates in P/Q control mode. For this diagram, work the output active and reactive power of the PV system is kept equal to the P_{ref} set value (depending on radiation intensity and heat solar degrees) and Q_{ref} (equal to 0). The inverter is synchronized to the power grid using a PLL block.

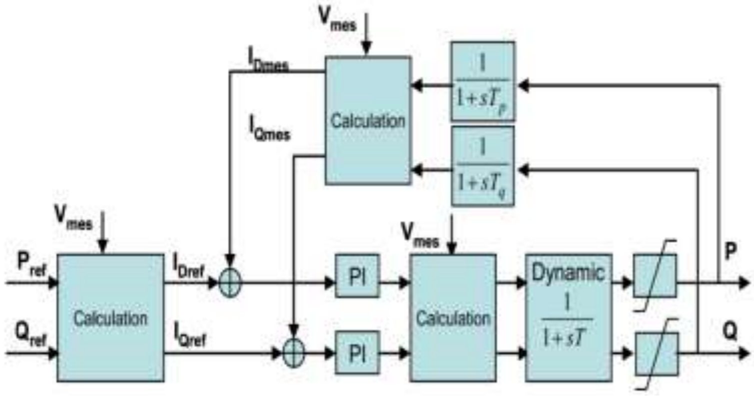

Figure 1.P/Q power control diagram

The operating principle of this scheme is described asFigure 1, from the measured current and voltage at the connection point, We can determine the power (P_{mes} and Q_{mes}) and the corresponding voltage response. These capacities will be regulated by two regulators proportional-integral (PI) control. Difference between installed capacity P_{ref} and Q_{ref} and power measurement P_{ref} and Q_{ref} will be handled by the set ratio (Kp) and integrator (Ki/p). After going through the PI department, I resigned output power, we can calculate the injected current thanks Park transformation:

$$\begin{cases} I_d = \dfrac{2\left(P*V_d + Q*V_q\right)}{3\left(V_d^2 + V_q^2\right)} \\ I_q = \dfrac{2\left(P*V_q - Q*V_d\right)}{3\left(V_d^2 + V_q^2\right)} \end{cases}$$

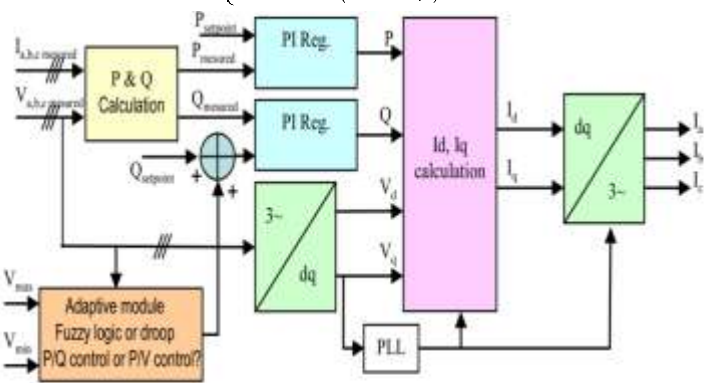

Figure 2. Voltage adaptive automatic control diagram

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Figure 2 introduces the voltage adaptive automatic control scheme. PV system models are built for 3-phase and 1-phase. This model includes 2 control modes P/Q andP/V control. With P/V control mode, set voltage(setpoint) is automatically changed adaptively, byhow to use fuzzy logic module. Change in prices the value of the applied voltage is set corresponding to the activationPV system's operation and connection location and power dependencies limited reactive power of each PV system.

Operating principle of the voltage regulation algorithmcorresponding to the following 3 control modes (Figure 3):

- Normal mode: When the voltage at the connection point is within the "desired" voltage range ($V_{min\_desired} \leq V \leq V_{max\_desired}$). In this mode, the PV system will operate in power control (P/Q) mode (or PF/VAR voltage control).

- Disturbed mode:occurs when the voltage at the connection point is outside the desired voltage limits ($V > V_{max\_desired}$ or $V < V_{min\_desired}$). The principle of adaptive control is to maintain the voltage (within the limits of the system) within this range of fixed values. Therefore, in a disturbed state, the PV system switches to operating in voltage control mode (P/V control). Here only reactive power is used to regulate the voltage at the PV system connection point. The applied voltage $V_{min\_desired}$ or $V_{max\_desired}$ is determined depending on the voltage configuration of the device grid power is too low or too high. If the reactive power of the PV system reaches the allowable limit ($Q = Q_{min}$ or $Q = Q_{max}$), it cannot ensure the desired voltage regulation anymore. The set voltage switches to dangerous mode when the voltage at the connection point exceeds the allowable limit.

- Dangerous mode:occurs when the voltage at the connection point exceeds the allowable limit ($V>V_{max\_admissible}$ or $V<V_{min\_admissible}$, for Vietnam grid $V_{max\_admissible}$ = 1.1 pu, $V_{min\_admissible}$= 0.9 pu) and as explained above, system Solar power cannot regulate voltage by capacity protest again. So, in a dangerous state, things

Active power control becomes necessary. So systemPV switches to active power control mode, yesthat is, the PV system changes the active power outputto bring the voltage within allowable limits.

Switching operating modes of the system Solar energy is carried out automatically and spontaneously adapt.

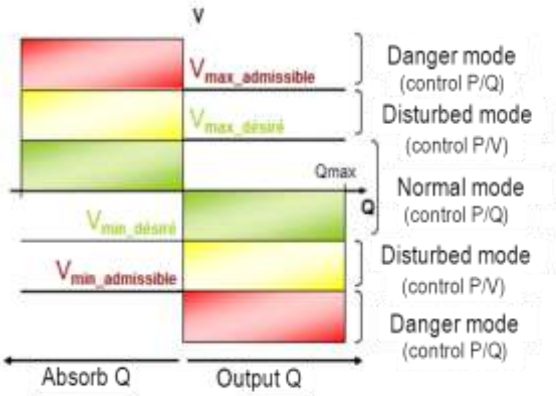

Figure 3. Operating principle of the voltage regulation algorithm

Desired voltage range

The controller adaptively changes the output desired voltage value (corresponding to the states) by adjusting the reactive power within limits allowed by each PV system. Besides that, depends on the voltage value on the output it connects to and the amount of workoutput or consumption power, voltage values Vmin_desired and Vmax_desired will change. If the voltage measured at the termination point The closer to 1 pu the desired voltage range of the controller more narrowed. This voltage range moves by amount

reactive power emitted or absorbed compared to the genders The physical limitations of the PV system are considered. Contribution of The more important the reactive power is, the greater the voltage range expand and follow the rule $V_{min\_admissible} \leq V_{min\_desired} \leq V_{max\_desired} \leq V_{max\_admissible}$.

This voltage adaptation is done using uses an adaptive module based on a fuzzy logic control algorithm. Fuzzy logic is chosen because of its functionality its interpolation. In fact, this logic is more accurate than logic Boolean to adjust the desired voltage range according to each voltage and reactive power measured at the connection point.

III. APPLY

To test the effectiveness of the control algorithm adjust the voltage at the point of

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connecting the PV system to the grid, one The power grid as shown in Figure 4 is studied.

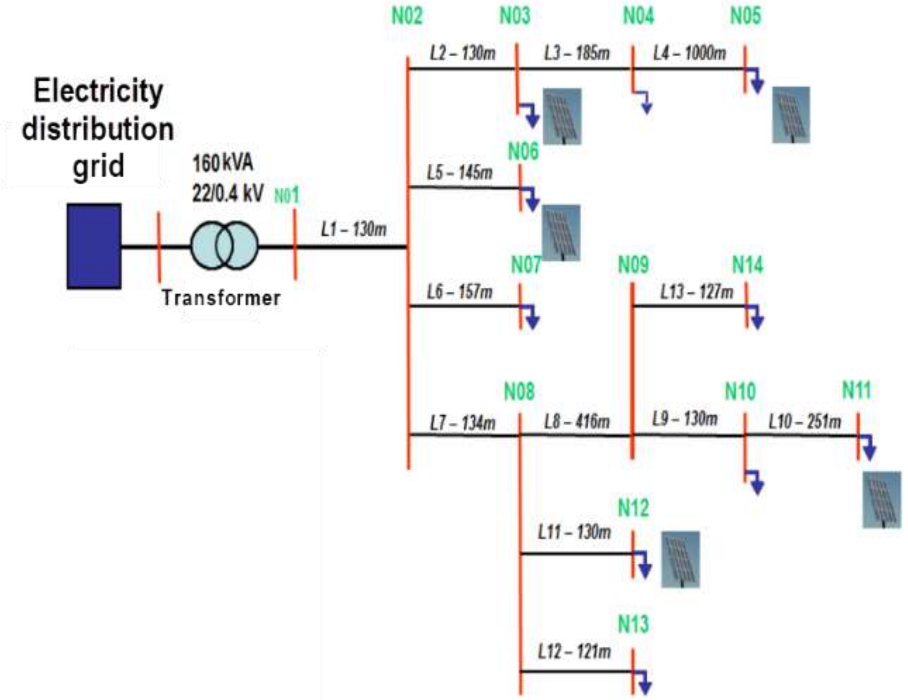

Figure 4. Distribution grid diagram

The distribution grid is powered from transformer station 22/0.4kV, 160 kVA, including 14 nodes, 10 load nodes and 5 systems solar power. The load at node 3 is a 3-phase load and the other nodes are loaded is a 1-phase load.

Low voltage distribution grid connected to solar power system simulated using Matlab-Simulink.

Two types of solar power systems are used:

- 3-phase PV system is connected at node N03 (30kW).
- Single-phase PV system is connected at nodes N05, N06, N11, N12 (3kW).

Two control algorithms of PV inverters are used:

- Classic control (P/Q control).
- Adaptive voltage control.

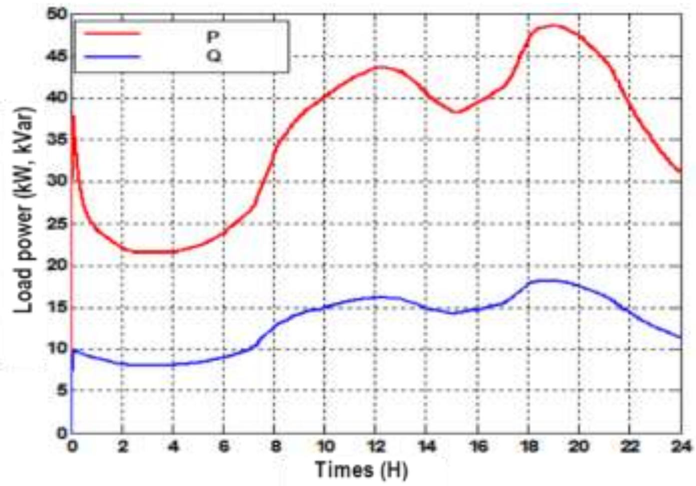

Figure 5. Load change graph during a day and night

Figure 5 shows the variation of 3-phase load at node 3 in 1 day and night.

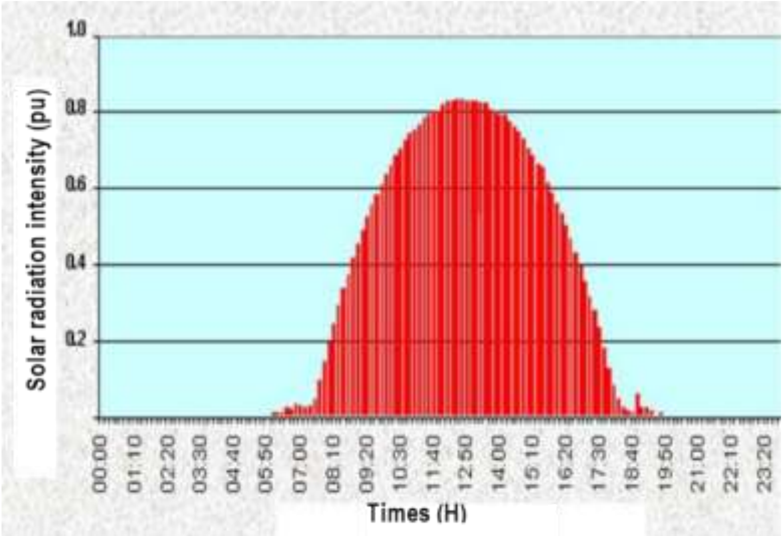

Figure 6. Solar radiation intensity in 24 hours

Figure 6 introduces the solar radiation intensity for 24 hours used in the simulation.

For P/Q control algorithm

In this case, we assume that all systems PV systems all operate according to public control algorithms P/Q rate.

Figure 7 shows the capacity of the PV system connected at button N03 (3 phase, 30 kW). PV system output power changes with solar radiation intensity corresponding to Fig 6. Reactive power in this case is kept equals 0.

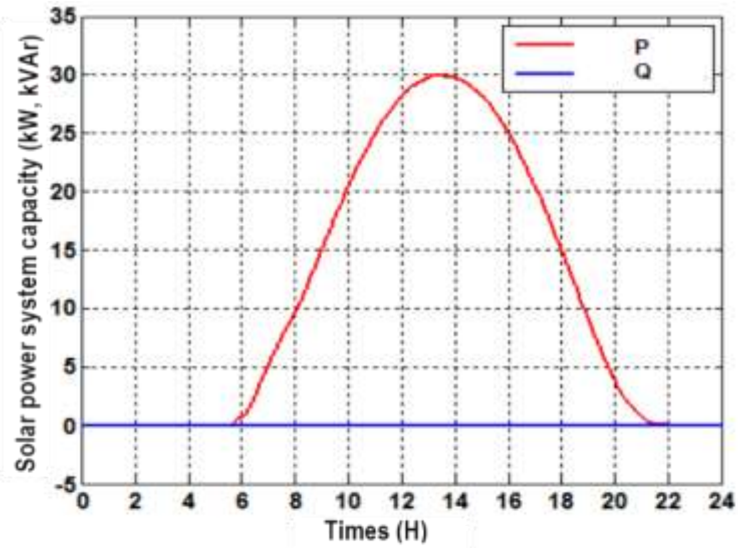

Figure 7. Capacity of PV system connected at node 3 (3 phase, 30 kW)

After connecting the PV systems to the downstream distribution gridvoltage, we have a voltage graph at the nodes on the grid as shown in Figure 8.

Figure 9 is the 3-phase voltage at node N05 when there is a PV system (1 phase, 3 kW) connected to phase c.

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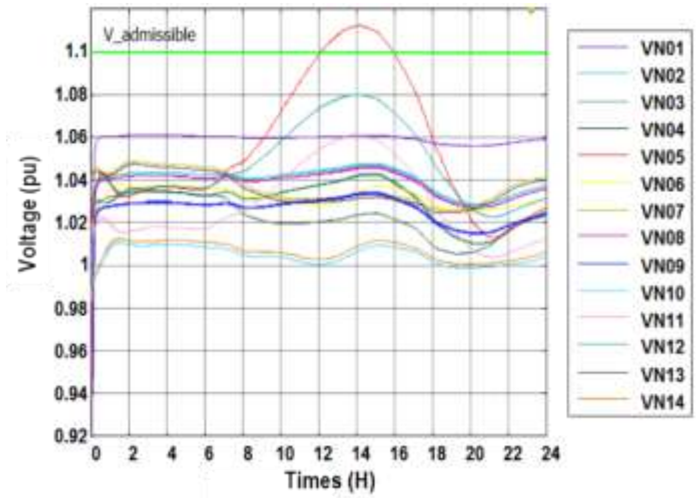

Figure 8. Voltage at nodes on the grid when connected solar power systems

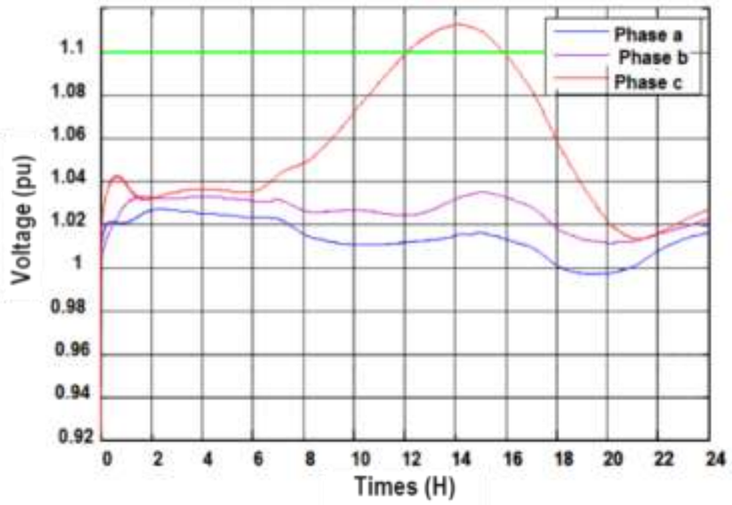

Figure 9. Voltage at node N05 with PV system (3 kW) Connect to phase c

Based on the simulation results, we see that:
- With classic P/Q power control algorithm (Q=0), there is an overvoltage phenomenon at node N05 (V> 1.1 pu, Fig 8), at a time when the intensity of the sun shines strongly.
- For single-phase PV systems when connected to the grid, there is loss balance between phases and overvoltage when the PV system is connected connection (For example: overvoltage on phase c at node N05).

For voltage adaptive control algorithm
In this case, the grid parameters and

The scenarios are similar to the previous case, but here All PV systems are self-regulatingvoltage suspicion. Figure 10 introduces the voltages at the nodes on the grid electricity when the PV system has adaptive voltage regulation. Brand The results of applying the control algorithm are shown more clearly in Figure 11.

As in the previous case, the output power of the systemPV systems vary according to solar radiation intensity. But in this case, the reactive power changes. To reduce the overvoltage phenomenon caused by the PV system pumping active power, reactive power is absorbed (power generation - Q). Figure 12 shows the output power of the PV system connected at node N05 (phase c, 3 kW).

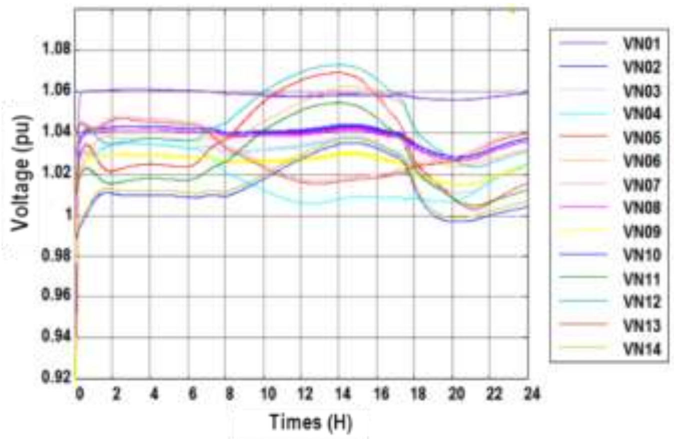

Figure 10. Voltage at nodes on the grid when the PV system has adaptive voltage regulation

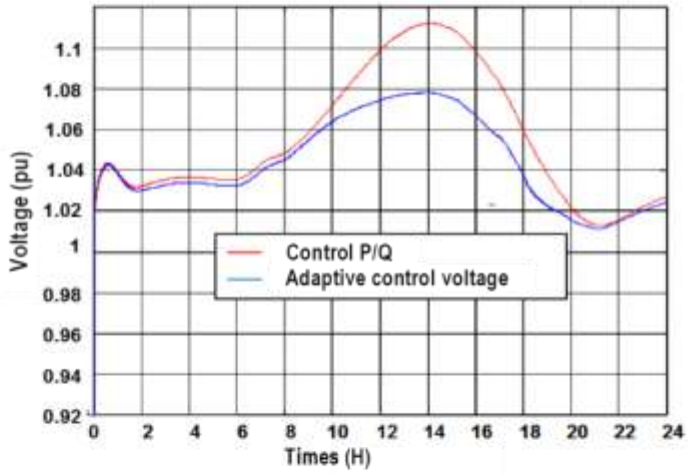

Figure 11. Voltage at PV system connection point when without/with adaptive voltage regulation

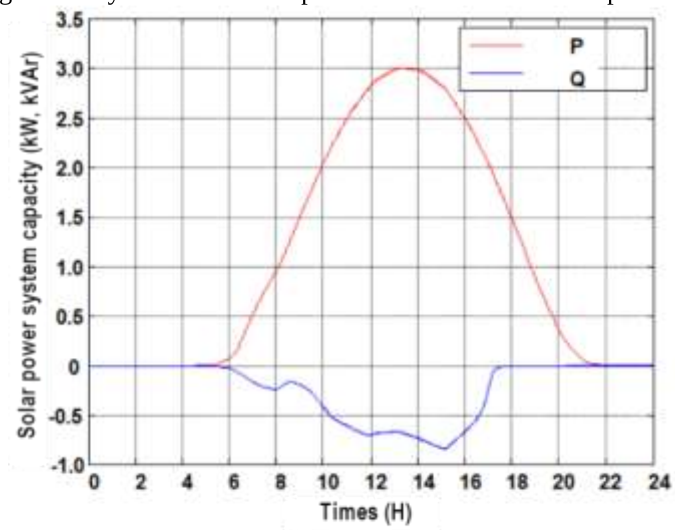

Figure 12. Output power of PV system connected at node N05 (phase c, 3 kW)

The degree of reactive power absorption depends on Various factors such as connection location, supply capacity reactive power of PV systems, grid voltage andgrid parameters... With appropriate adjustment algorithm suspecting the voltage (Figure 10), we find that all node voltages kept within allowable limits (0.9 pu – 1.1 pu) and copper while reducing voltage phase imbalance.

IV. CONCLUSION

This article introduces the adaptive voltage adjustment algorithm at the distribution grid connection point of the solar energy system. This algorithm has many advantages:

- Able to keep voltage within allowable limits (0.9 pu - 1.1 pu).
- No need for any communication system.
- A good solution to reduce voltage imbalance in low voltage distribution networks.
- Absorbs reactive power only when needed and thus limits power loss in the line.
- Operates automatically.
- Increase the penetration of solar energy into the power system, increase the efficiency and flexibility of connecting PV systems to the grid.
- Not only to adjust the voltage at the connection point but also applies to every point on the grid.

This voltage control algorithm is suitable for solar energy systems connected to the low voltage distribution grid.

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