Evaluating the Algorithm of PV Units Disconnection for Alleviating the Grid Congestion

A. S.M.Emara, B. A. M. Soliman, C. M. S. El-bages, D. E. M.Saied, E. M.M.Salama

Abstract—Electrical network congestion is a technical problem, which occurs in transmission lines and cabling due to insufficient transfer capabilities and line outages in the systems. Congestion problem is resulting from many of reasons. One of these reasons is the surpluses resulting from PV units. This paper discusses this reason, how to solve this problem and give an evaluation of this solution. Disconnecting the consumer with its PV from the network is our proposed solution for this trouble. One of the tool techniques which used for optimum selection of units to be disconnected is the Particle Swarm Optimization Algorithm (PSO). This solution enters the consumer in islanding mode in which will be evaluated. The paper provides some of recommendation for correction action.

Keywords—On Grid PV Surpluses, Congestion Management, Islanding.

I. INTRODUCTION

In electrical network, congestion can be appeared when producers and consumers of electricity want to produce and consume in amounts that would cause the network to operate more than its transfer limits. The congestion problem reasons may be appeared in several ways: lack of coordination between generation and transmission utilities, installation of the customer may increase the fault or current rating of network equipment, sudden increase in load demand and power surpluses produced from solar units [1]. System congestion must be managed to raise the network productivity and quality of service. There are two basic types that can be used for congestion management: cost-free means and not-cost-free means. The first type take into account the actions like outages of the congested lines or operation of the transformer taps, phase shifters, or FACTS devices. These means are named as cost-free only due to reason that marginal costs taken in their usage are nominal. The second look into the network sensitivity factors methods, security constrained generations re-dispatch, congestion pricing and market-based methods and application of the FACTS devices [2]- [3].

In the last few years the amount of distributed generation (DG) in the electric network has been increased due to the technical, economic and environmental benefits they offer. DG based on solar energy, wind, biomass and mini hydro will increase in the future. In Egypt the numbers of Photo Voltaic (PV) panels connected to the distribution networks are increasing as a result of the government encouragement to the investors to invest in the establishment of projects for the production of electricity from renewable energy sources. The investor will get its power and sell the surplus to the grid. The distribution networks were not originally designed to accommodate the surplus power which in turn will create a congestion problem. Therefore, it is required to manage the problem of congestion such that the network not congested. There are several ways for solving the congestion resulting from PV surpluses: sell the surpluses when consumption is low, store surplus energy as much as possible for later use and disconnect number of investors with its PV units which violate the Available Transfer Capability (ACT) from the grid. Recently, the last method may be used for congestion management by using several algorithms. As this solution success for solving the congestion problem, there was a trouble appeared with it, which the disconnected part will enter in islanding phenomena. In islanding, the DG continues to supply a power to a load after the main grid disconnected from the network. In power system point of view islanding can play vital role in the system reliability, which reducing interruption durations in the event of a system failure and therefore decrease electricity outage cost of customers. But in some utilities, islanding not allowed because of the safety hazards imposes by it, further more to prevent abnormal voltage and frequency on the system.

Safaa Emara is with the Electronics Research Institute, Dokki, Giza, Egypt

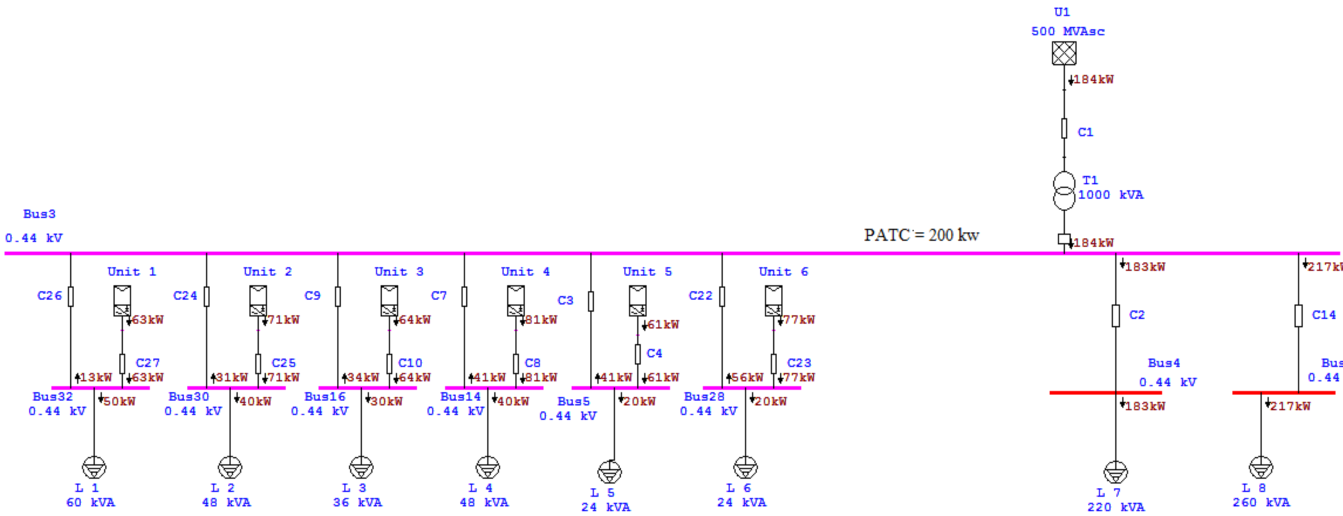

Fig. 1. Case study load flow

In this paper a real case study in Egypt presented to discuss the forming, impacts and evaluation of islanding. The example shows that some of PV units connected to the clients, each client will take its need from its PV and sell the surplus to the grid. When the total surplus excess to the available transfer capability of the grid, the congestion problem will be appear. To solve the congestion, selected clients with its PV will be disconnected from the system, the islanding is forming, and a great attention is given toward the islanding because it causes a several technical issues to be discussed and evaluated through this paper.

II. Network Congestion Resulting from on Grid PV System

Congestion is a technical problem which occurs in the systems in both regulated and deregulated power system, but most of the time occurs in deregulated manner due to competition in power producers and consumers. There are many faces to the congestion, one of them is the power surpluses produced from solar units on rooftops or on ground. The congestion resulting from the power surpluses produced from solar units can be alleviating by disconnecting some of them. In this section a real case study in Egypt will be discussed.

The case here as shown in Fig.1.consists of consumer demand of 600kw (8 consumers) feeding from transformer (1000KVA), six of consumer with load power (200kw) owned PV units accommodate to ATC (200kw). The load flow of the system is implemented by using the Electrical Transient Analyzer Program (ETAP), the power of the PV units can meet the load of consumers. The excess power (surpluses=216kw) can return to the grid to feed other users. Since the line capacity cannot hold the residual surpluses which it is above the Available Transfer Capability (ATC) value, disconnecting some of the consumer is our approach to congestion avoidance. Particle Swarm Optimization algorithm (PSO) was used for selecting the disconnecting consumer according to less power surplus flowed to the grid, more units joined to the grid and minimum tariff for the joined units, which was the consumer number six as described in table 1.

TABLE.1.

SELECTED UNIT BY PSO ALGORITHM AT (PATC =200KW)

Units	*Surpluses* (KW)	*Tariff* (pt)	*Selected units*
1	13	40	1
2	31	60	1
3	34	60	1
4	41	70	1
5	41	80	1
6	56	120	0

Running the proposed algorithm and optimization technique for another case which surpluses=280 KW and PATC =60KW, the selected consumer was consumer number 1, 2. But when PATC =60KW and surpluses=250 KW the selected consumer was consumer number 3, 4. Any way when the selected consumer disconnected from the grid the loads become in islanding mode.

III. Islanding

The process of islanding is the changing of section of the utility system while the DGs are still connected from a normal operation into island mode. Islanding can be categorized into two terms [4]-[5].

A. Unintentional Islanding

Unintentional (unplanned) islanding indicates to a part of the grid to be self- separated from the network due to faults or others grid disturbances. After formation of islanding a possible safety hazard for operations personnel represented since lines may still be alive when they are assumed to have been disconnected. Further, during an islanding event the DG unit is not capable of controlling the level of power quality in the network which may result the possibility of equipment damage. On the island, protections systems are expected to be uncoordinated due to the strong change in short circuit current availability. Breakers or circuit reclosers of the utility are necessary to reconnect the island to the grid when out of phase. An inrush current following the breaker out of phase reclosing, this flows between the grid and the DG. The current can damage the protection breakers and other equipment. The equipment may be damage in a number of ways. For example, insulation is damaged when equipment is operated over its design temperature. This state is often a result of increased I2R losses through an overload. Moreover, in motors, generators and transformers an overvoltage condition causes core saturation.

For these reasons, islanding detection (anti-islanding) techniques is essential in order to detect the islanding operation instantly. Various anti-islanding detection methods have been developed in [6]. Islanding detection can be categorized into two schemes [7] as local detection schemes and communications-based detection schemes.

The first is classified into two categories as active detection schemes and passive detection schemes.

For active methods, which are called "active" as they are based on the observation of the effects appeared by inject signals into the grid. These methods are usually implemented in inverter applications, as were studied in [8, 9]. But in passive detection schemes, the measured voltage and current signals used to identify islanding conditions. Under voltage or overvoltage resulting from the reactive power mismatch level between the local generation and the local demand discover islanding system.

The second detection schemes usually use the status of disconnecting switches and circuit breakers to discover an islanding condition. It can be determined based on a predefined logic condition in central processing unit or programmable logic controller which monitors the breaker and disconnecting switch statuses.

B. Intentional Islanding

Intentional (planned) islanding is referred to a part of grid, with fixed or variable extension, in which any distribution generation are present, able to support the appropriate frequency and voltage levels. Such intentionally islanding operation is useful, for example, due to permanent faults or during scheduled maintenance. Recently intentional islanding operation takes into consideration by some utilities to actually use the available renewable energy generation, but it affected by some factors: the staff safety, keeping voltage and frequency in the allowable range and possibility of non synchronization between islands and the main network after the fault is removed [10]. These attentions must be required before starting any islanding operations, so some papers proposed an algorithm to control the switching of loads to create islands [11]. In another paper a new approach based on the Imperialist Competitive Algorithm (ICA), is handed for determining the optimal intentional islands in networks [12]. In [13] the problem has been modeled as a Knapsack Problem (KP), which is also used as a determining factor for connecting all the selected buses. Some utilities do not allow intentional islanding because the trouble that appeared after this operation so, some studied the impact of intentional islanding, which observed that care and suitable load shedding are required in formation of island [14]- [15]. In this paper and as described in section 2, we are fall in intentional islanding, hence another case study will be shown in the next section to investigate and evaluate the islanding effect based on the proposed algorithm for alleviating the congestion problem.

IV. Case Study in Egypt

Fig. 2. illustrates a Matlab simulation of a case study which matches the standard service voltage in Egypt in which 100-kW PV array connected to a 22-kV grid via a DC-DC boost converter and a three-phase voltage source converter.

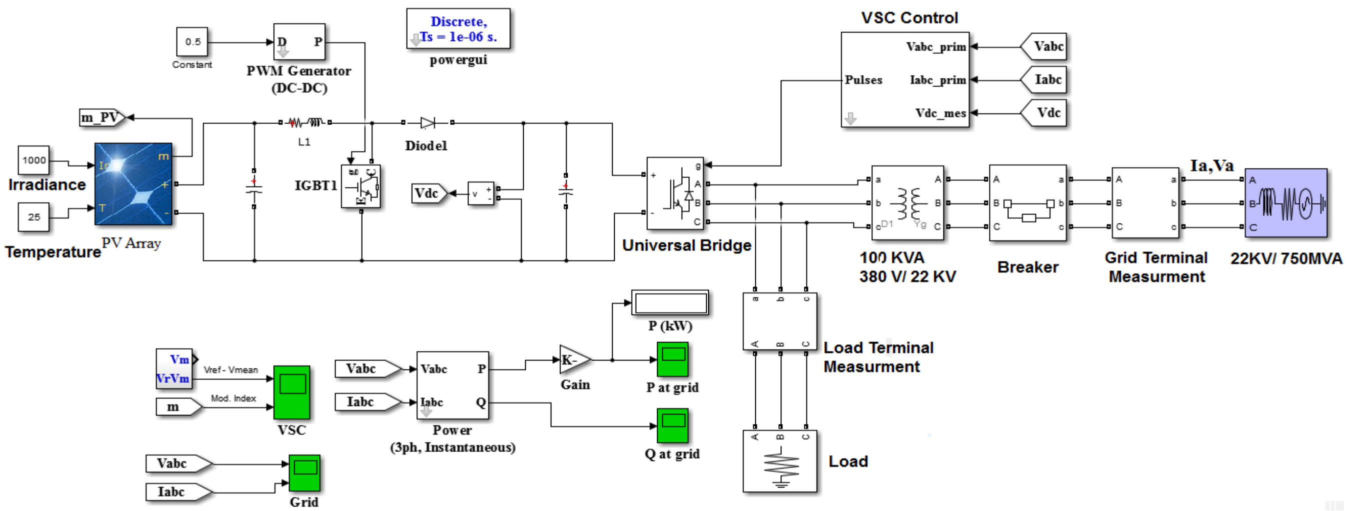

Fig.2. Case Study Matlab Simulation

The characteristics of the PV module simulated by the PV simulator during the simulation period are:

Open-circuit voltage, Voc= 64.2 V

Short-circuit current, Isc = 5.96 A

Maximum power output voltage, Vmp =54.7V.

Maximum power output current, Imp = 4.7 A

For simplification of the analysis, the simulation is executed only at a fixed solar irradiation of 1000 watt/m2 and 25º Celsius. In order to produce a total output dc voltage of 350V with a power capacity of 100KW, 42 strings connected in parallel each string consists of 8 modules connected in series. Then, by using the DC to DC boost converter, the voltage step-up to 700V to match the inverter input voltage for generating phase voltage of 220V. The inverter control strategy applied consists of two cascaded loops, the fast inner current control loop, which regulates the grid current, and an outer voltage control loop, which controls the dc-link voltage.

The current control loop is responsible for power quality issues and current protection. The dc-link voltage controller is designed for balancing the power flow in the system. In this model, a synchronous reference frame control is chosen, it is also called as dq control. It uses a reference frame transformation module, abc to dq to transform the grid current and voltage waveforms into a reference frame that rotates synchronously with the grid voltage so that the control variables become dc values. Thus, filtering and controlling can be easily achieved. The phase angle used for the abc to dq transformation module is obtained by the Phase-Locked Loop (PLL). The generated ac voltage and current contain undesired harmonics components which can be reduced or eliminated by the filter. As a result, the generated ac power from the inverter is supplied to the load and then forward to the grid whenever there is a surpluses power available. The case is done through the means of grid connecting devices, the breaker.

V. SIMULATION RESULTS AND ANALYSIS

A simulation in MATLAB/Simulink is shown in Fig. 2. It was running for 2 seconds, the breaker is open at time 1 sec and closed at 1.5 sec.

Upon case study described in which generated power from PV is 100KW and a load power is 70KW that mean the rest of power will be to the grid, the grid voltage waveforms, Va, get perfectly sinusoidal waveform as shown in Fig 3.

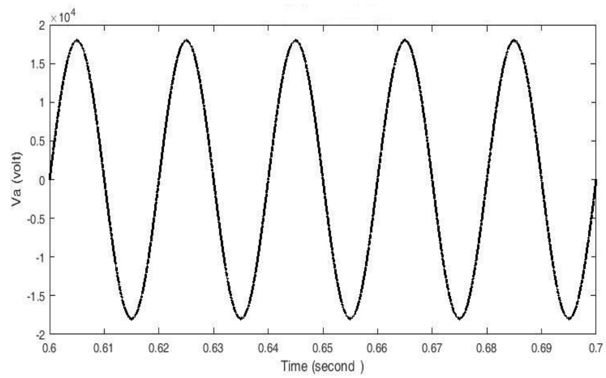

Fig.3. Va at the grid terminal

Similarly, it can be seen that the current waveforms posses almost the same sinusoidal shape during the operation modes as shown in Fig. 4.

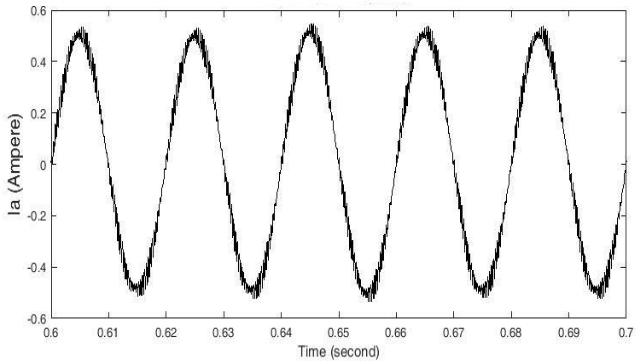

Fig.4 Current at the grid terminal

Fig. 5 shows the excess power to the grid during the transient conditions, opening the breaker at time (1 sec) "Islanding" and closing the breaker at time (1.5 sec)"Reclosing".

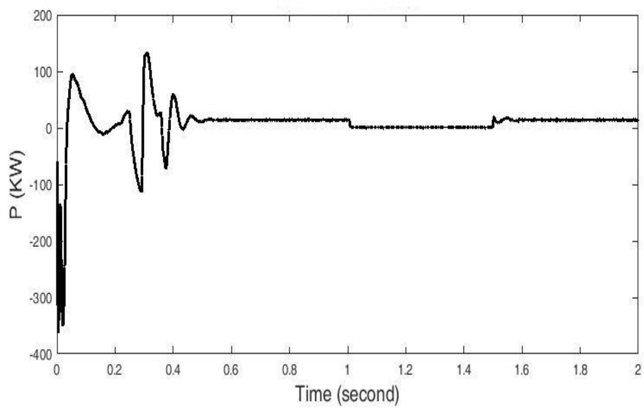

Fig.5. Power at the grid terminal with Load (70kw)

While fig.6. shows the grid current during opening/closing the breaker

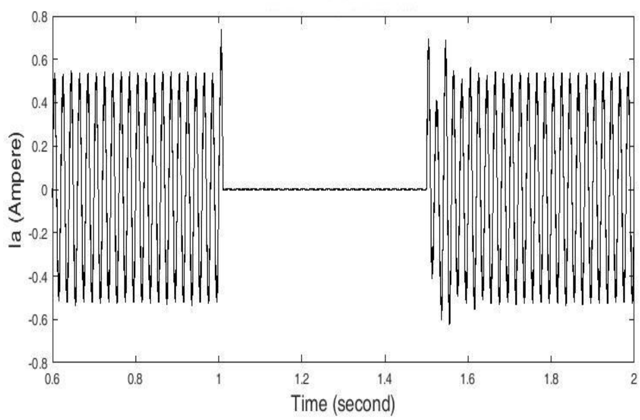

Fig.6 Ia at the grid terminal

As shown from fig .6. a high transient oscillation is appeared during the instant of reclosing. This oscillation can affect on electrical distribution system, transient degrade the contacting surfaces of switches, disconnects, and circuit breakers. Also the transformers are forced to operate inefficiently because of the hysteresis losses produced by transients and can run hotter than normal. Whereas, when the breaker is open at time (1 sec), the voltage of the load will be increased above its nominal voltage as shown in fig 7. And the load current will also increase as shown in fig.8.

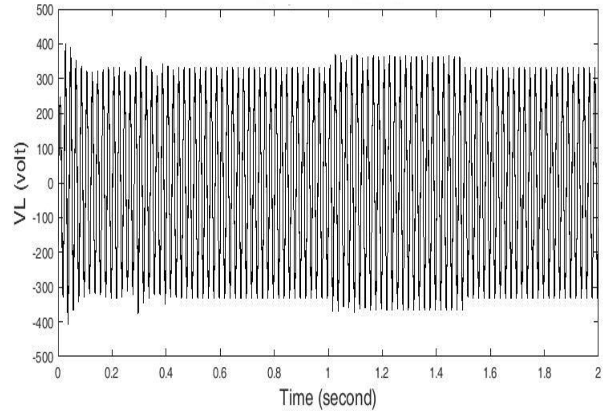

Fig.7 Voltage at load terminal (70kw)

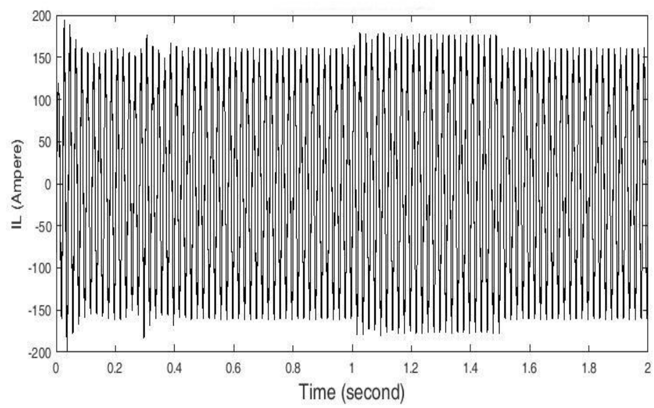

Fig.8. Current at load terminal (70kw)

Another situation running will be done to demonstrate this issue deeply for a load power is 120 kw. In this case, the grid will participate with the PV in feeding the load as shown in fig.9.

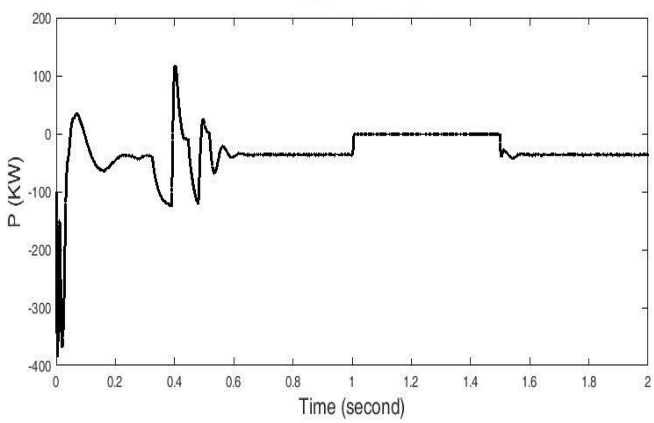

Fig.9. Power at the grid terminal with Load (120kw)

Fig 9 shows additional power is drawn from the grid which was indicated by -20kW at the grid contribution profile.

Fig 10.shows the load voltage, when the breaker is opened which inter in islanding mode, a system disturbance voltage at the load will be decreased, this mean that we obliged to shed some of loads.

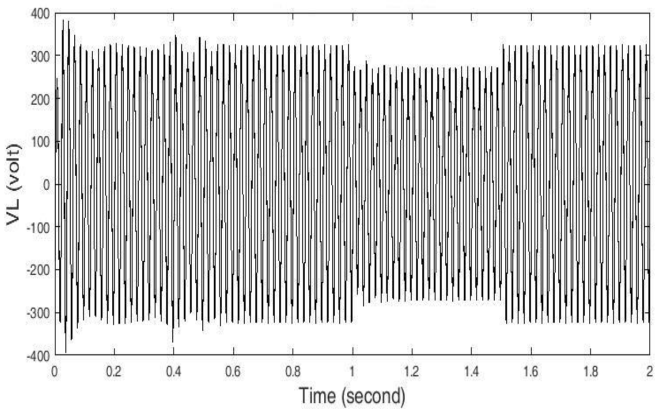

Fig.10 Voltage at load terminal (120kw)

VI. Evaluation of Proposed Solution and Recommendation

The proposed solution for alleviating grid congestion providing disconnection of selected PV units consumer according to many of criteria, Available Transfer Capability (ATC) value of the system, maximum connected consumer and minimum tariff will enter the consumer in islanding mode which has some of drawbacks as described above as a result we recommended the following:

- When selecting the disconnection solution, a sophisticated control must be connected in consumer side to overcome the islanding problems, this will impact a high cost for the consumer.
- By using the methodology for identifying which consumer will present the surplus, this consumer still connected but its surplus will be used for any purpose, such as controlling the surpluses to be stored in different schemes or using it for heating purpose.

VII. Conclusions

The paper discusses the electrical grid congestion, the management of congestion by disconnecting the client with its PV from the system. The results show that this solution is not ideal because disconnection will go the client into islanding mode. The islanding mode has many of drawbacks which the DG unit is not capable of controlling the level of power quality in the network. So, the paper recommends if the system fall in intentional islanding, the system must be a composed with high level control of power quality with its relative cost impact, otherwise avoiding of islanding is advised and the surpluses of PV units will be directed to another solution such as: controlling the surpluses to be stored in different schemes or using it for heating purpose.

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