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# Reconfiguration Method Based on DC/DC Central Converter within Different Mismatch Conditions

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## Abstract

Reconfigurable photovoltaic (PV) systems are of great interest with respect to system designers in order to improve the system's efficiency and operation. This paper proposes an adaptive reconfiguration scheme to reduce the effect of shadows on solar panels. A method to capture the maximum power point of the photovoltaic (PV) array systemwith the help of DC/DC central converter system is presented. The method of connecting the solar adaptive string to the fixed part of the solar photovoltaic (PV) array proposed, which increases the power of the solar PV array according to a model-based algorithm. The model algorithms are implemented in real time. Ideal diode model parameters also proposed for each module in both fixed and adaptive part respectively. The analyses are obtained from the study of the voltage vs. power curve characteristics of the both parts. Finally, the proposed solution is ensuring that the adaptive string has the ability to capture the MPP.

**Keywords**: Photovoltaic (PV) system, Adaptive string, Fixed part, DC/DC central converter, Maximum power point (MPP)

## Introduction

Day by day the generalized interests of the using renewable energy sources are increased as alternative energy to cover the increasing demand in the different applications in a sustainable and clean. Particularly, the using of the PV power plants increases year by year (IEA, 2010 http://www.iea.org/papers/2010/pv_roadmap.pdf) not only in terms of the advantages of this type of energy, but also from the financial incentives side and the regulations become implemented for many countries (J. Zhao, E. Mazhariet al, 2011). However, until 2011 about 28 GW were implemented in the scope of International Energy Agency (IEA) countries for totally installed energy of 63.6 GW, when more than 62 GW correspond to the applications of centralized and distributed grid-connected system (IEA, 2012,http://www.iea-pvps.org/). The PV systems may operate in mismatch conditions depending on that place characteristics due to many surrounding objects like the surrounding buildings, trees, clouds, dust, etc. (B. Liu, S. Duan,2012;Y. Wang, P. Hsu,2010). These mismatching conditions can produce large loses in that generated power since the voltage vs. power characteristic curve of the photovoltaic array shows multi maximum power point (MPP), when each one of these MPP is less than the global power of any one of these modules (G. Petrone et al,2011;G. Petrone et al,2007;K. Ishaque et al,2011). The amount of drop in the electrical power depends on the general shape of the voltage vs. power curve, which is normally defined by the temperature and irradiance distribution over the whole array and the PV configuration itself to interconnect to the panels (M.Z. Shams El-Dein, 2012).

There are different configurations in operation of PV system modules connections, the most one used are Total Cross-Tied (TCT) and Series-Parallel (SP) and beside to it is possible in the literature to find another configurations like Honey Comb (HB) or Bridge-Linked (BL) (Y.-J. Wang*et al*, 2011). In case the TCT configuration method the modules are connected in parallel first which named rows, then connected in form of series forming the PV array. In case the SP configuration method the modules are connected in series to form groups of strings, then these strings groups are connected in form of parallel forming the PV array. In the traditional TCT and SP configurations the interconnection operation of the PV modules normally is fixed. However,by using a switch matrix the PV connections can be changed totally to get more decreasingof the mismatching conditions effect (Y. Zhao, L, 2011;Y. Zhao, L,2012;D. Nguyen, B. Lehman, 2008). These systems are called reconfigurable arrays systems which lastly have a gained popularity due to the increase at the output of the maximum power available of the PV generation systems under different mismatching conditions (M.Z.M.A. Shamseldein, M. Kazerani, M. Salama(2012); M.Z.M.A. Shamseldein, M. Kazerani, M. Salama).

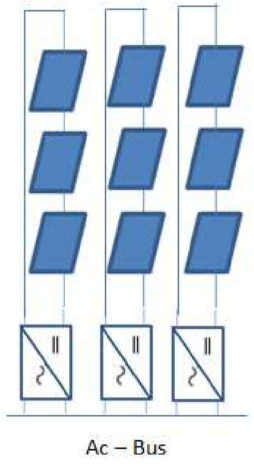
In the literature different methods proposed to offer the best configuration way for the PV array showed in (Y. Zhao, L. Yang, B. Lehman, 2012;G. Velasco-Quesada*et al.*2009; Z. Cheng, Z. Pang, Y. Liu, P. Xue, 2010; M. Alahmad, M.A. Chaaban,2012).In (G. Velasco-Quesada*et al.*2009) the authors proposed a reconfiguration method of a SP array by reducing, or balancing as much as possible, the difference between the irradiance levels in each parallel string. In the proposed solution the irradiance level of each module of the array is estimated by a method of central DC/DC converter to test all the feasible configurations to determine which of them will provide the highest Maximum Power Point (MPP). Furthermore, the solution requires measuring the current and voltage in each module alone to guess the irradiancelevel by using the single ideal diode model, but it will not supply a method to figure out the parameters for each modules.

Therefore, this paper is focused on string DC/DC converter configuration; also the method is applicable to SP configuration with need to some of modifications. The paper is organized as follows: Section 2 presents types or methods to configure the photovoltaic systems under different issues and different conditions. Section 3 introduces and presents the application of the proposed solution to reconfigure a PV array. Then, Section 4 presentsthe discussion of the results by analysis the PV performance within different mismatch conditions. Finally, Section 5 Conclusions close the paper.

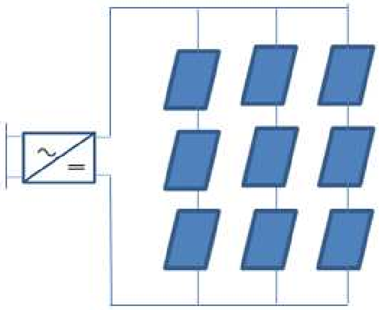
## Existing PV system Configurations

The Reconfiguration architecture is a great benefit in operation of system design. This interest has been more momentum since the technological improvements and advances in the system components which become more and more modular, and allow for innovation and greater design flexibility. In the utility interactive system, the simplest of the system design, operation of reconfiguration is done by adding a component into the system to improve its efficiency. Until now in the literature the following configurations were done: String inverter, central-inverter; team inverter; module inverter configuration, and multi-DC/DC-central inverter.

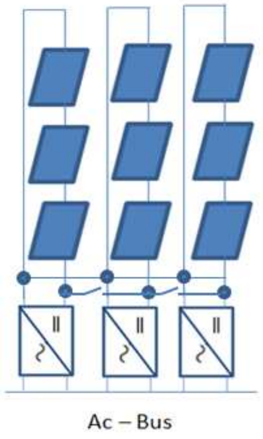
The following section will precedes a brief explanation for each configuration. The PV strings are all connected to one incorporated box, then the box to a central inverter which converts the produced power from case to case (DC to AC) then supply to the grid. But this type of configuration cannot exactly tracking the MPP for the whole system, as shown in Figure 1a (Dunlop, 2010; Myrzik and Calais, 2003; Kjaer et al., 2005). The second one is the central inverter system, which Comprises of several strings and one inverter, each string consists of a fixed number of the PV series connected modules, as shown in Figure 1b. This because of each alone string has one MPP and separated from the others according to the shadowing effect and operational conditions. The other one is the team-inverter configuration, which shown in Figure 1c, in this type of configuration used a controllable switches to give a permittivity of connecting the parallel string inverters together according to the solar condition (Myrzik and Calais, 2003). This system allows connecting the adequate number of the strings in parallel with a nominated number of parallel inverters, then as a result will maximize the efficiency for the connected inverters. Within low irradiance case, the power generated from the string in the PV configuration does not agree with the optimal efficiency of working of the inverters. Thus, gathering the parallel PV strings will lead to increase the generated power to agree with the optimum operating point for the selected inverter(s). The module-inverter or (micro-inverter) system, shown in Figure 1d, the single module almost connected with its own inverter which can operate alone near to the MPP of the module. This is effective increasing of the efficiency of the complete system (Dunlop, 2010; Sherif and Boutros, 2002; Myrzik and Calais, 2003). By using this topology, a 5–20% more of the energy can be acquired over the life of the PV system (Lalonde, 2011). Finally, in the Multi DC/DC-central inverter system configuration, shown in Figure 1b, the central inverter system during shadowing conditions will make to improve the performance of the system by adding a DC/DC converter to each string. In this type of configuration, the advantage is that the tracking of MPP is available for each one of the string independently (Dunlop, 2010; Myrzik and Calais, 2003; Kjaer et al., 2005). In the Multi-String inverter configuration, shown in Figure1C, can find that any string has its own inverter alone and all these inverters can operate in parallel together to supply power to the load. In this system can be increased the system efficiency, but will take more cost (Dunlop, 2010; Myrzik and Calais, 2003; Kjaer et al., 2005).



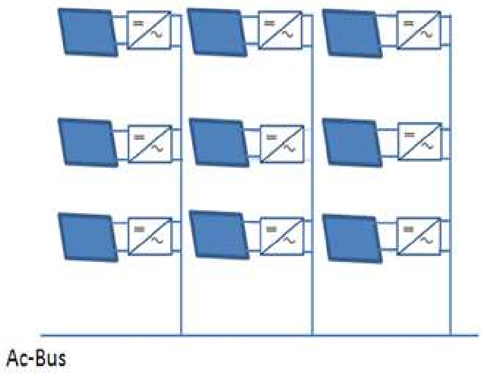
(a) The configuration of string inverter



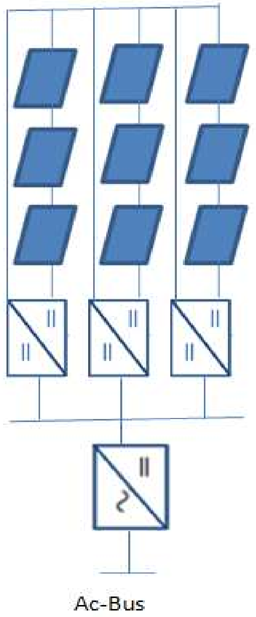
(b) The configuration of central inverter



(c) The configuration of team inverter



(d) The configuration of module inverter



(e) The configuration of Multi Dc-Dc central inverter

**Figure 1 Different type of configurations and connections available in the PV systems.**

## The Proposed Adaptive Utility Interactive System

It was presented a Flexible Switch Matrix (FSM) in Alahmad and Hess (2008, 2010). This type of matrix was integrated to be with a group of PV modules to lead to form of the Elastic Structure (ES) of the PV. In this integrated structure, is achieved the fault tolerant design and the full flexibility by connecting two types of modules adjacent and non-adjacent in order to increase energy capture during the shadow conditions, soiling,

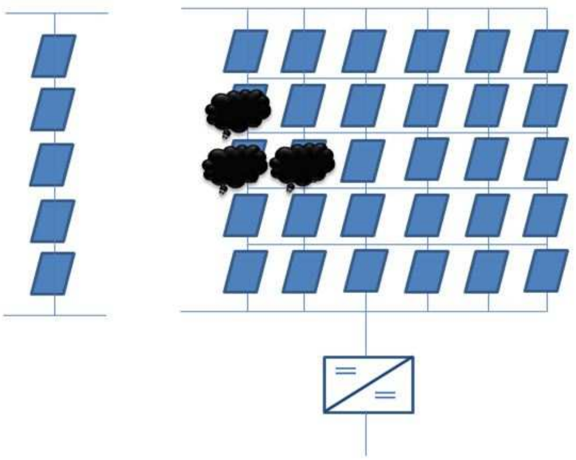


**Figure2 proposed PV system configuration with adaptive and fixed parts central DC/DC converter**

mismatching, and other effects in real time. The ES is gathered with a DC/DC central converter and with an adaptive PV string to provide a flexible and interactive utility system, as shown in Figure 2 above. This system is a combine between the configurations presented before in Figure 1a–d, and introduces a more flexible connection in order to make rearrangement for the PV modules in the real-time and according to the availableoperationalconditions.

The proposed system is consisting of: an Elastic Structure combining the FSM and the PV modules; DC/DC converter centered the fixed model; and system of power management (controller device). By using the ES, the most efficiently configuration that is extracting the maximum power point from the existing PV is also selected. The configuration operates under the normal conditions as a central inverter configuration (Figure 1b) beside to the DC/DC converter is disconnected from the PV system (i.e. isolated). However, if current and/or voltage mismatches cab be occurring in both adjacent and non-adjacent PV modules, then the ES PV system will maximize the power captured by reconfiguration the PV itself. In this case, the PV system will achieve and select the best PV configuration to hold the most power, which otherwise may be eliminated because of the static configuration for the many configurations known traditionally. Furthermore, employing management and reconfiguration a more than one string are composed and directly connected to the centralized inverter, and the DC/DC converter is employed (if was needed) to link the other remaining modules (excepting the moduleswas affected) to connect the inverter to a partial string. An example for this case, when shading across somePV modules occurs a significant reduction of the generated energy from the PV system will be occurs, which lead to additional losses (Chaaban and Alahmad, 2010). In the shaded module the hot spot is capable to sustain the cell level under the permanent damage. The famous conventional method in reducing the shadow effect on the PV module is to insert a bypass diode. Usually in this method requires integration for the bypass diodes at both module and cell level, but results in power lost and further cost. Over and above, many peaks can be present in the output of the PV power curve which leads to further losses in the system. Therefore, an optimum maximum power point tracker must be inserted to follow the global power peak in the power curve and at the same time avoided the appearance local peaks (Esram and Chapman, 2007; Saiju, 2008). Another example, is unequal voltage between the strings due to the mismatching effect which leads to unbalance voltages between the modules in the entire strings (Chew and Siek, 2010; Kjaer et al., 2005) cause to reduce the efficiency of the system.

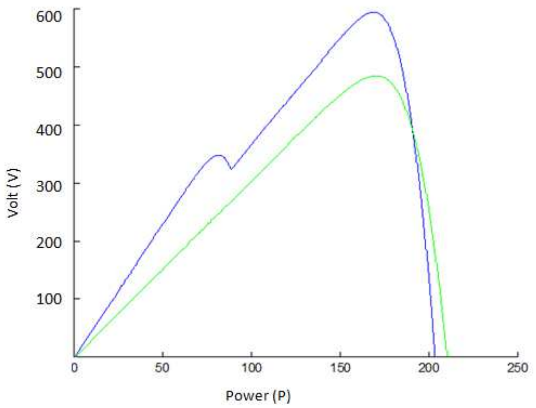


**Figure 3 PV characteristic before recovering with mismatch conditions.**

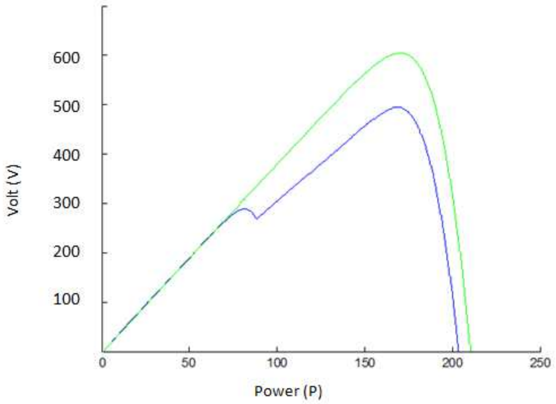


**Figure 4 PV characteristic after recovering with mismatch conditions**

will be demonstrating in Figures 3 and 4 provide a PV characteristic for the output curves of both traditional fixed and the adaptive systems during the shadow conditions. Therefore, in the following section will describe and explain the ability of the system, and its benefits in capturing the MPP, and operation under different conditions.

## Results and Analysis

Figure 3 and 4 show the results of the PV system for three-shaded modules in the fixed part before and after the recovery respectively, two in the first string and one in the second string, which will be recovery by reparation it from the adaptive string. As can be seen from the figure, the results of the simulated system can be express on the effect of the bypass diode on the shadowing. The adaptive PV string help in capturing the peaks of the fixed system are because of finding the bypass diodes. Furthermore, Figure3 and show the results of effect the adaptive string on the shadowing occurs to the fixed part and three shaded modules (two in the first string and one in the second string respectively). Moreover, the results improved by capturing the energy when utilized the adaptive system in these operational conditions. Also from the simulation results can be seen that the maximum energy captured when the adaptive system connect to the fixed one when any three nonadjacent modules are shaded. The efficiency of the DC/ DC converter will be reduced the energy captured from one module in this case. The main reason for this is energy capture reduction that the DC/DC is only can capture one module, while the other two remaining modules will configured in a form of a string and will connected to the inverter directly. The lowest efficiency occurs in the adaptive PV system when be a complete string in that system is not available (more than 5 modules shaded). In this situation, the total efficiency in the system are decrease as the actual efficiency of the DC/DC converter. Fortunately, this condition will still generate convincing efficiency improvement within the fixed system.

## Conclusion

This paper proposed the DC/DC central converter parallel series interconnections of photovoltaic arrays. As applicable case studies verified in this work, the interconnection has the ability to acquire a significant reducing in the mismatch losses when compared with other conventional Total-Cross-Tied (TCT) or Series-Parallel (SP) interconnections without any use of switches or sensors. This is power loses reduction is provide a significant enhancement in the photovoltaic structures design, and it is useful especially in the stage of planning for the large photovoltaic architecture. The flexibility of the interconnection also results in a smoother array – characteristic with a way to capture the maximum power point in different mismatch conditions. Beside to it is try to lower the number of the local maxima power point by compensate the shaded modules from the adaptive string. Furthermore, the future work will investigate other algorithms as solution which could be requiring a more suitable in case of large arrays with different shading patterns.

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