Photovoltaic System Reconfiguration strategy for mismatch condition

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***Abstract*—This document is a model and instructions for LaTeX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

As the world of fossil energy constantly exhausted and the increasingly serious environmental pollution, the research and utilization of renewable energy and green energy have become maintain necessary means of survival and development of the human. Photovoltaic (PV) energy received significant attention since it has unlimited energy and easy to be scaled up. Thanks to extensive technology and research on photovoltaic energy generation, large scale photovoltaic energy generation system have been deployed into many practical application. But due to PV arrays are senstive to shading and PV cell's fault or aging. That means when interconnection of PV cells or modules do no have identical properties or experience different conditions from one another. PV arrays are in mismatch condition. In order to avoid mismatch condition damage PV cells, we proposed an algorithm that can re-configurate photovoltaic arrays to minimize mismatch loss.

In this paper, we using non-uniform irradiance levels to represent mismatch condition and analyzes the efficiency of a PV system under different shaded working condition is presented. When photovoltaic arrays operating in non-uniform irradiance levels may present multiple local maximum power points (MPPs) [1], which been generated by turning on bypass diodes. By changing electrical connection among the panels to prevent activate bypass diodes is a recent appealing solution [2].

The main difficulty facing the reconfiguration problem is that some or even all panels can be subjected to partial shading, so there may be more than one MPP for each panel. Reconfiguration strategy need also consider to group PV modules which provided high power separately [3] [4].

This procedure enables to detect panel's operating conditions, in more than two-strings, receiving different irradiance levels. The reconfiguration algorithm will analyzes panels' working conditions and reorganizes panels into different strings by different irradiance levels. However, in sparse of mismatching conditions, distribution of panels among different irradiance levels are not significant. For that, by increasing number of strings in the PV array and using exhaustive search can be a solution [3].Another approach to optimize photovoltaic arrays is using genetic algorithm [5]. However, computing cost is too significant, and this algorithm can't detect best configuration precisely.

II. Assumption of a PV array

In this paper, we using following definitions of PV arrays, modules, strings and panels. A PV array formed by several parallel connected PV strings, and string is several series connected PV panels. For a PV panel, formed by two or three PV modules connected in series with bypass diodes. An equivalent connection as showed in Fig. 1.

Fig. 1. Definition of PV array and internal components.

The algorithm we proposed based on following assumptions.

- The current versus voltage (*I-V*) curve of each panel calculated by algorithm presented in [6]. This algorithm will analyzes panel's *I-V* curve sample and coordinate to maximum or minimum power point in *P-V* curve.

- All the panels in PV array have same number (N) of modules. For particular module, using (V_{mpp_n}, I_{mpp_n}) to identify MPP voltage and current by index n. Those parameter can be directly estimated by the prosess provided in [7].

Furthermore, it is also assumed that for each string it has same number of panels in PV array. Means every string in PV array have same length. String's length are identical based on when they connected in parallel, a string has more panels may cause current back flow into other strings which have less panels [8].

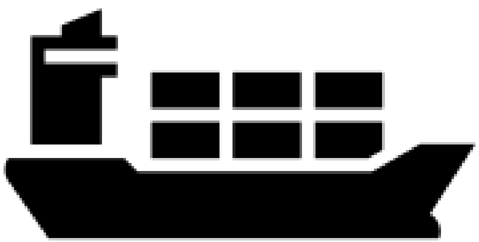

Fig. 2. Flowchart of reconfiguration algorithm.

III. Reconfiguration Algorithm

The general steps of reconfiguration algorithm are presented in Fig. 2. The first step is determine each PV module's V_{mpp} and I_{mpp} by using algorithm provided in [7] [9], and calculate MPP current and voltage candidates of PV array. When there are more than two panels connected in series, for a string MPPs is not straightforward. The MPP current and voltage candidates can be evaluated though a procedure presented in [10]. For string MPP current candidates, I_{mpp_n} values' different less than 5% are assumed to be equal. For string MPP voltage candidates, V_{mpp_n} can be calculated though multiplay number of active modules (N_a) by average MPP voltages ($\bar{V}_{mpp}$) with $\pm$18% error [10]. Afterward, determine real number of working modules (Q_{M_n}) per string by applying method in [10]. Next, find MPP candidates by multiplying current candidates and voltage candidates which determine by Q_{M_n}. Due to $V_{mpp}s$ and $I_{mpp}s$ can indicate shadowing distribution among PV array. Then grouping panels into different shadow levels. Then grouping panels by different irradiance levels.

After this procedures is conducted for PV array, all panels will be sorted into many groups that from un-shadowed to fully shadowed group. However, if just simply grouping panels by shadow conditions it may cause electrical connection overhead or unable calculate optimal configuration. To further reconfigure PV system into a better configuration, the replacement part of algorithm will proceed as follow:

- Sorting group by different irradiance levels, select panels from first group into a PV string which working on high current level.
- If selected panels' working modules ($Q^*_{M_n}$) less than Q_{M_n} , select panels from next irradiance level group.
- If selected panels' $Q^*_{M_n}$ more than Q_{M_n}, re-select panels to adjust $Q^*_{M_n}$ equal to Q_{M_n} if it is possible.

Fig. 3. Flowchart of reconfiguration algorithm.

This algorithm will better understood by applying to shadow condition showed in Fig. 3. This PV system is composed with 9 PV panels connected into 3 strings as showed in Fig.3. Irradiance levels, I_{mpp} and V_{mpp} of each module are given in Table I

TABLE I
Table Type Styles

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The example refer to a three-strings PV array, each string contain with 3 panels, each one made of three identical PV modules (N=3). In this example, it is assumed that input range of DC-DC converter and MPPT device defined by V_{min} = 200V and V_{max} = 500V. MPP current candidates and MPP voltage candidates are present in (1) and (2), respectively. Additional, number of real working module at MPP current candidates are given in (3).

$$I_{mpp_n} = [\{0.5_{(9)}, 0.5_{(9)}, 0.5_{(9)}\}, \{0.5_{(9)}, 0.5_{(9)}, 2_{(11)}\}, \{0.5_{(9)}, 0.5_{(9)}, 3_{(4)}\}, \{0.5_{(9)}, 2_{(11)}, 2_{(11)}\}, \{0.5_{(9)}, 2_{(11)}, 3_{(4)}\}, \{0.5_{(9)}, 3_{(4)}, 3_{(4)}\}, \{2_{(11)}, 2_{(11)}, 2_{(11)}\}, \{2_{(11)}, 2_{(11)}, 3_{(4)}\}, \{2_{(11)}, 3_{(4)}, 3_{(4)}\}, \{3_{(4)}, 3_{(4)}, 3_{(4)}\}] \pm 5\% \quad (1)$$

$$V_{mpp_n} = [12, 4, 24.8, 37.2, 49.6, 62.0, 74.4, 86.8, 99.2, 111.6] \pm 18\% \quad (2)$$

$$Q_{M_n} = [\{8, 8, 8\}, \{8, 8, 8\}, \{4, 4, 4\}, \{7, 7, 7\}, \{4, 4, 4\}, \{2, 2, 2\}, \{5, 5, 5\}, \{4, 4, 4\}, \{2, 2, 2\}, \{1, 1, 1\}] \quad (3)$$

Due to 5% error of MPP current candidates and 18% error of MPP voltage candidates, total error rate of MPP candidates is 23%. Though procedure of algorithm, MPP candidates with 23% are: [{ 0.5, 0.5, 2}, {0.5, 2, 2}, {2, 2, 2}, {2, 2, 3}] and require working modules per strings are: [{8, 8, 8}, {7, 7, 7}, {5, 5, 5}, {4, 4, 4}]. Those MPP candidates are able to generate maximum output power of PV system, but the configurations of MPP candidates may meet electrical connection overhead. In order to reduce electrical connection simulation time, replacement and feasibility check will be approved.

Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sections III-A–III-E below for more information on proofreading, spelling and grammar.

Keep your text and graphic files separate until after the text has been formatted and styled. Do not number text heads—LaTeX will do that for you.

A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

B. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as "3.5-inch disk drive".
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- Use a zero before decimal points: "0.25", not ".25". Use "cm^3", not "cc".)

C. Equations

Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \quad (4)$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use "(4)", not "Eq. (4)" or "equation (4)", except at the beginning of a sentence: "Equation (4) is . . ."

D. LaTeX-Specific Advice

Please use "soft" (e.g., `\eqref{Eq}`) cross references instead of "hard" references (e.g., `(1)`). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

Please don't use the `{eqnarray}` equation environment. Use `{align}` or `{IEEEeqnarray}` instead. The `{eqnarray}` environment leaves unsightly spaces around relation symbols.

Please note that the `{subequations}` environment in LaTeX will increment the main equation counter even when there are no equation numbers displayed. If you forget that, you might write an article in which the equation numbers skip from (17) to (20), causing the copy editors to wonder if you've discovered a new method of counting.

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E. Some Common Mistakes

- The word "data" is plural, not singular.
- The subscript for the permeability of vacuum μ_0, and other common scientific constants, is zero with subscript formatting, not a lowercase letter "o".
- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
- A graph within a graph is an "inset", not an "insert". The word alternatively is preferred to the word "alternately" (unless you really mean something that alternates).
- Do not use the word "essentially" to mean "approximately" or "effectively".
- In your paper title, if the words "that uses" can accurately replace the word "using", capitalize the "u"; if not, keep using lower-cased.
- Be aware of the different meanings of the homophones "affect" and "effect", "complement" and "compliment", "discreet" and "discrete", "principal" and "principle".
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- There is no period after the "et" in the Latin abbreviation "et al.".
- The abbreviation "i.e." means "that is", and the abbreviation "e.g." means "for example".

An excellent style manual for science writers is [7].

F. Authors and Affiliations

The class file is designed for, but not limited to, six authors. A minimum of one author is required for all conference articles. Author names should be listed starting from left to right and then moving down to the next line. This is the author sequence that will be used in future citations and by indexing services. Names should not be listed in columns nor group by affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization).

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Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is "Heading 5". Use "figure caption" for your Figure captions, and "table head" for your table title. Run-in heads, such as "Abstract", will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced.

H. Figures and Tables

a) Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation "Fig. 4", even at the beginning of a sentence.

TABLE II
TABLE TYPE STYLES

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Fig. 4. Example of a figure caption.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an example, write the quantity "Magnetization", or "Magnetization, M", not just "M". If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write "Magnetization (A/m)" or "Magnetization {A[m(1)]}", not just "A/m". Do not label axes with a ratio of quantities and units. For example, write “Temperature (K)”, not “Temperature/K”.

ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression “one of us (R. B. G.) thanks . . .”. Instead, try “R. B. G. thanks. . .”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

Please number citations consecutively within brackets . The sentence punctuation follows the bracket. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first . . .”

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the abstract or reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors' names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

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