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INTEGRATION OF PHOTOVOLTAIC SYSTEM TO THE GRID AND OBTAIN MPPT USING FUZZY LOGIC CONTROL

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Abstract:
In grid connected photovoltaic (PV) systems, maximum power point tracking (MPPT) algorithm plays an important role in optimizing the solar energy efficiency. In this paper, fuzzy logic control based MPPT method has been proposed for searching maximum power point (MPP) fast and exactly. This paper presents the integration of photovoltaic system to the grid control with power electronic converters and control strategies are discussed. Initially mathematical modelling of PV module is done, to extract maximum power from PV system a boost converter is designed and fuzzy logic control is implemented to track the maximum power point. A voltage source full bridge DC-AC converter for interfacing between PV system and single phase grid. A single phase grid is connected to the PV system using a single phase inverter where the gate pulses of the inverter is pulse width modulation technique(PWM). The voltage and current control is provided by the PI and PR controller and also phase locked loop is provided for fixing the phase shift. interconnection between grid and inverter is done by LCL filter to reduce the harmonics in grid current.

Key words- *Photovoltaic system, fuzzy logic controller, boost converter, maximum power point tracking, single phase voltage source full bridge Inverter, grid, Proportional integral controller and Proportionalresonant.*

1. Introduction:

Fossilfuels (oil, coal and natural gas) have been throughout history, the backbone on which industrial activity has been developed and nowadays, they are the main energy resource of an industrialized society and also they have been the responsible of inequalities between countries with a limited access to this kind of resources, hindering their development. Photovoltaic (PV) energy is the outcome of the direct conversion of light energ yinto electricity. The conversion is achieved via thin semiconductor devices called photovoltaic cells, which are also sometimes called solar cells or PV cells. PV cells are basically flat light-sensitive diodes comprised of the same or similar materials as those used in transistors, computer chips, and related technology.

For utilizing the PV source optimally, it is required to provide an electronic controller in between source and load for various operating conditions. For operating the PV source at maximum power point(MPP) and for improving the PV system efficiency this convertor can be used . There are many control algorithms that have been reported in the literature for obtaining the maximum power from the PV system, such as neural network algorithm, fuzzy logic algorithm, constant voltage (CV), perturbation and observation (P&O), incremental conductance(INC).

The figure shown in Fig.1 mainly consists of three subsystems PV system, boost converter to extract maximum power from PV system, dc–ac converter for interfacing between PV system and single phase grid, and fuzzy logic control is implemented to track the maximum power point.

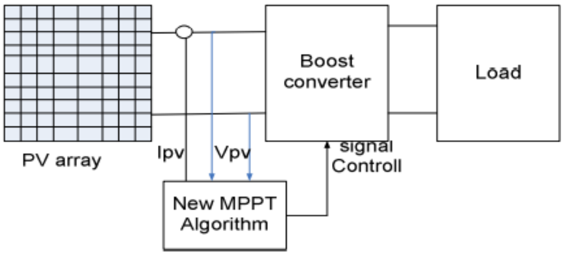

Figure 1. Grid integration with Photo Voltaic (PV) system

PV system inputs are non-linear in nature (solar irradiance, temperature) operates with fuzzy logic control for obtaining ma ximum power point tracking with boost converter. The PV system supplies power to AC grid connected. In this a single phase dc-ac voltage source inverter is used for converting DC – AC for interfacing with grid using proportional resonant controller and proportional integral controller. The details PV system modelling, boost converter, dc-ac converter, tracking of maximum power point and integration with the grid are discussed in below sections. The simulation results for the system are explained and presented considering the output waveforms as shown in Section 4.

2. MODELLING OF A PHOTOVOLTAIC MODULE:

Photovoltaic cells are produced in a variety of types, each of which has different benefits such as Mono-crystalline (single-crystalline) cells - these types of cells derive from a single crystalof silicon and are quite smooth in texture, Poly-crystalline (multi-crystalline) cells - these type of cells are several crystals combined and they are cut from a block of silicon, Amorphous cells - cells are produced by settinga thin film of non-crystalline (i.e., amorphous) siliconon top of differentsurfaces.

Photovoltaics exhibit non-linear features, meaning that both output power and performance are significantly impacted by any alterations in operating conditions such as solar irradiance, moisture levels, and temperature. In Figure 2, we can observe the PV system I-V plot and P-V plot.

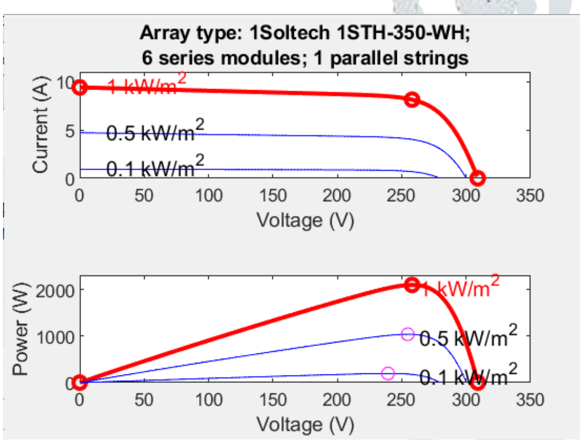

Figure 2: I-V and P-V curves of photovoltaic system

2.1 Equivalent circuit and Mathematical model:

A modified step-by-step process for photovoltaic (PV) module simulation using MATLAB/ Simulink is presented in this work. To explore the I-Vand P-Vfeatures of a typical 260 watts monocrystalline solar panel, a single-diode equivalent circuit is used. However, it is essentialfirstto characterize a circuit-based simulation modelfor a PV cell prior to permitting any interaction with a power converter. Throughthe PVeffect, electromagnetic radiation fromsolar energy can be changed into electricity. When exposed to sunlight, photons with more energy than the semi-conductor's band-gap energy make electron-hole pairs that are proportional to t the incident irradiation. A solar cell is essentially a p-n junction set on a thin wafer of semiconductor.

As illustrated in Equations (2.1) to (2.4), the photovoltaic panelcanbe mathematically modelled

Module photo current: Iph = [Iscr+Ki (T-298)]*λ/1000 (2.1)

Module Reverse Saturation current: Irs = Iscr / [exp (q.Voc/Ns.k.A.T)] (2.2)

Here, we can see that the module's saturationcurrent Is varies according to cell temperature, givenas:

Is =Irs*[T/Tr] 3 exp [q*Ego {(1/Tr)-(1/T)}] (2.3)

The PV module current is thus: Ipv =Np * Iph -Np*Is [exp {(q*Vpv+Ipv*Rs)/NsAkT}] (2.4)

3. DC-DC CONVERTERS:

There are different topologies of converters. The three basic converters are buck, boost and buck-boost converter. Each of these is used to identify themost suitable topology for PV module maximum power point tracking performance. Fromthis, a model of the most suitable topology willbe generated andthis modelwill be used for a number of simulations aimed at identifying the impact of componentnon-idealities on the outputvoltageand efficiency of the converter. The results of these s simulations can be used to select converter components and developcontrolstrategies with the model of the converter forming the main section of a complete MPPT modelused for fuzzy logic controller tuning.

The average output andinput voltage andcurrentvalues for an optimisedboost converterare:

$Vo = Vg / (1-D)$

$Io = Ig (1 – D)$

The input side's load resistance R' is expressed as R' = R (1− D)2 .

The load seen by source can only be decreased by varying D as 0 < D < 1. As such, a boostconverter's tracker would only be able to extract maximum power when the PVmodule's maximum powerpoint current Imp is higher than the originalload. Under normalcondition, i.e. when the solar irradiance onthe entire PV array is uniform, the current- voltage (I-V) and power- voltage (P-V) curves exhibits a single globalmaximum power point . To understand the fast changing solar irradiance, two levels of irradiance that are different were selected, 1) high point (Point A, G=1000W/m2) and low (Point B, G= 300W/m2). It can be observed that, themaximum power point (MPP) has changedfrompoint A to B when the irradiance(G) level d decreases from 1000W/m2 to 300W/m2 .

3.1 Determining resistance value:

The relationship between optimalinternalresistanceof PV array at MPP (RMP) and load resistance (RL) of boost converter is expressed as

$$R_L = \frac{Rmp}{(1-Dmp)^2} = 79.25\Omega$$

3.2 Determining inductance value:

The value of boost inductor is selected based on the ma ximu m current ripple that is allowable which occurs at the ma ximum power point when the solar irradiance (1000W/ m2) is highest. The higher the ripple output current, the lower is the inductor value and vice versa. To design a low cost converter, the lower inductor value is preferred, because inductor is the most expensive component compared to the others. In this work, the permitted amount of ripple currentis selected as 40% of theinput current and theswitching frequency is set to 20 kHz. Hence, the minimum value of inductor is,

$$Lmin = \frac{Vmp*Dmp}{2*\Delta Iout*f} = 600\mu H$$

3.3 Determining capacitor value:

In this the input and output filter capacitor (Cin & Cout) are chosen in such manner that voltage ripple requirement of 0.2% is fulfilled. The expression for determining therequired capacitance value is givenas;

$$C = \frac{Vmp*Dmp}{2*\Delta Vout*R*fs} = 3000\mu F$$

4 Grid Connection:

The power converter interface from the dc source to the load or to the grid consists of a two stage converter: the dc-ac converter (inverter) and the dc- dc converter(boost converter). In the conventional solution with two-stage converter, the dc-dc converter requires many number of devices causing a high amount of conduction losses, slow transient response and high cost while there are many advantages of the single-stage converters such as high efficiency, a low cost andeasier implementation.

As shown in Fig. 3, the PV inverter consists of a solarpanelstring, a dc linkcapacitor , on the dc side with an ac outputfilter (LCL), grid connection on the ac side.

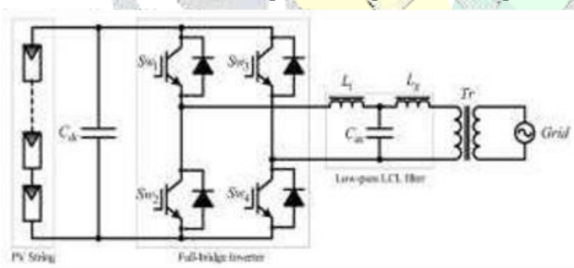

Figure 3: A voltage source PVinverter connectedto the grid using an LCL filter.

4.1 Phase LockedLoop(PLL) Structure:

The PLL is used to provide a unitypower factor operationwhich involves synchronizationof the inverter outputcurrent with the grid volta ge and to give a clean sinusoidalcurrentreference. The PI controllerparameters of the PLL structure are calculated in sucha way that we can setdirectlythe settling time and the damping factor of this PLL structure. The PLL structure is alsoused for grid voltagemonitoring in order to get the amplitude andthefrequency values of the grid voltage. Thegeneralformof the PLL structure is presented in Fig. 4.

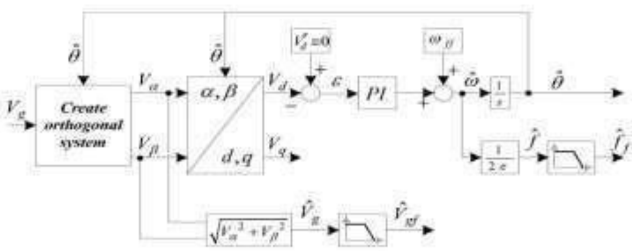

Fig. 4: Structure of a singlephase phase lockedloop

4. Grid Connection

4.1 Phase Locked Loop(PLL) Structure:

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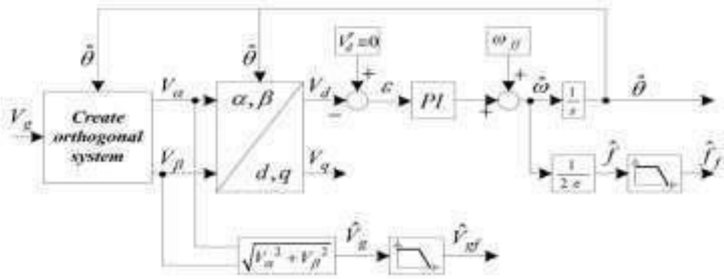

Fig. 3: Structure of a singlephase phase lockedloop

4.2 MPPT algorithm :

The main purpose of the MPPT in a PV systemenergy conversion is to monitor the systemcontinuously so that it draws maximum power from the solar array irrespective of the non-linear inputs such as irradiance, temperature. The solar panel has non-linear current-voltage characteristics as they depend on the conditions such as irradiance, ambient temperature, and wind which are non-linear so the output of the solar array are unpredictable, the tracker would monitor a nonlinear and time-varying system. The conventional maximum power point tracking algorithms are using dP/dV= 0 to obtain the maximum power point output. Many other algorithms can be used in order to obtain the MPPT such as: incremental conductance, perturb and observe, parasitic capacitance and constant voltage. However, the frequently used algorithms are the first two algorithms.

Fig 5: Fuzzy logic rules.

4.2.1 Fuzzy logic controller:

Fuzzy logic controller structure is basedon fuzzy sets wherea variable is a member of one or more sets with a specified degree of membership. Benefits of using Fuzzy logic are; it allows us to emulate the human reasoning process in computers, quantify imprecise information, make decision based on vague information such as resistive load is connected to the PVmodule through the boostdc-dcconverter. The blockdiagramof MPPT based fuzzy logic control is shown in Figure 6.

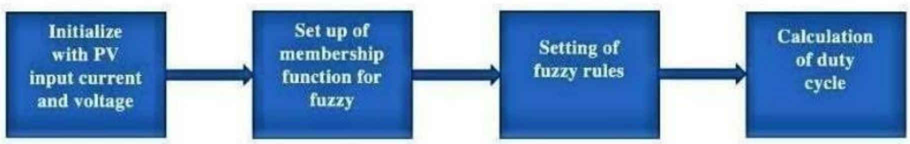

Figure 6: Block diagram of the fuzzy logic algorithm.

5 Simulation Results:

In this section the results fromthe Simulink model is discussed usingthe waveformresults. The waveforms are observedfor boost converter output voltage(V_{DC}), maximum power point tracking, grid current(I_{grid}) and grid voltage(V_{grid}).

From these below results we can observe that the integration of PVsystem to the grid is done with less harmonics usingthe control strategies that are designed to avoid the harmonics. The MPPT is done by using fuzzy logic controller. A full bridge inverter model is designed for grid connectionfor converting the DC to desired ACoutput as the grid parameters are 50Hz and 230V. The /MATLAB Simulinkmodel is shown as below.

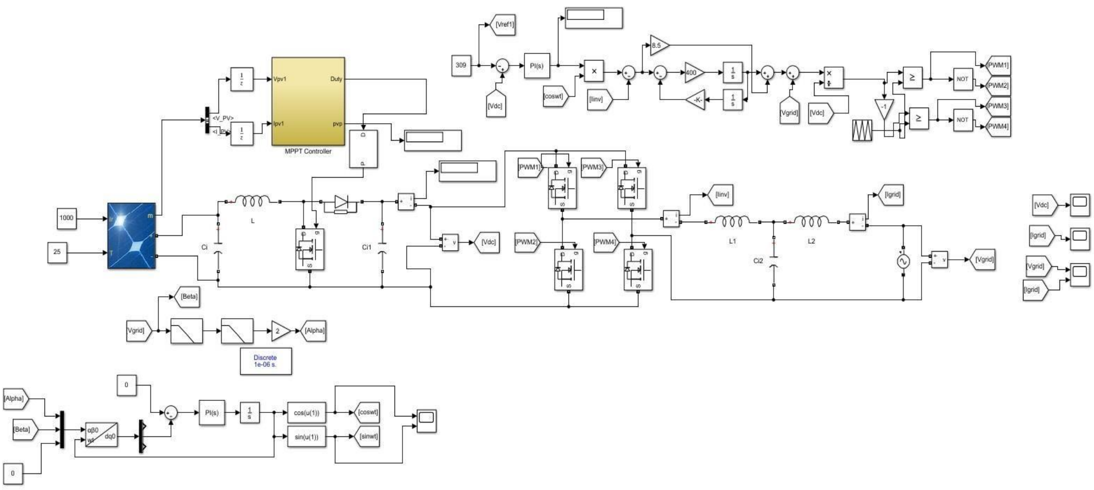

Fig 7: Integrated PV systemwith single phase gridSimulink model.

5.1 Analysis of Simulink Results:

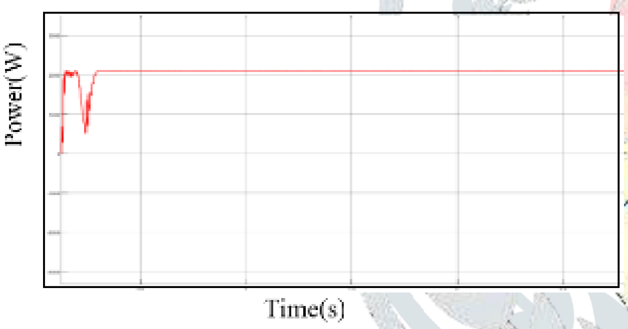

Fig 8: Maximum power point tracking(MPPT).

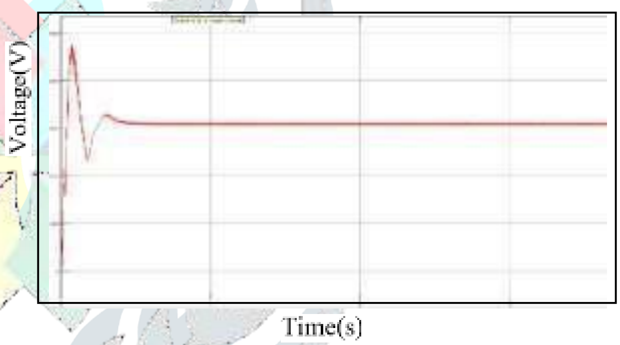

Fig 9: Boost converter voltage(Vdc).

The maximum power output is extracted fromthe photovoltaic module by usingmaximum point tracking in this paper Fuzzy logic control is usedfor maximum power point trackingand themaximum power obtained is 2096W.

The output voltage of the boost converter is observed from the graph, initially the voltage is fluctuating at time 0.75sec it started to settle down. The voltage is settles around 309V. This output voltage of the boost converter is considered as Vdc and this voltage is used for tuningthe PI controller by comparing with reference voltage Vref.

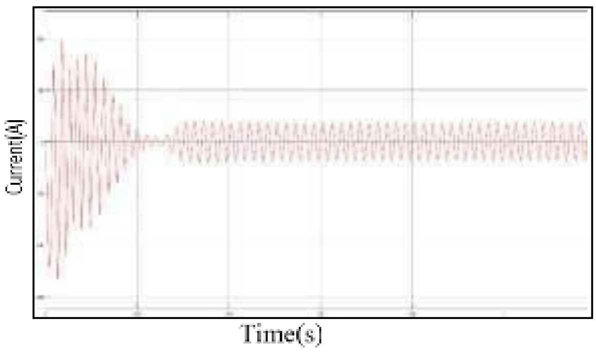

Fig 10: Grid Current(I_{grid}) waveform

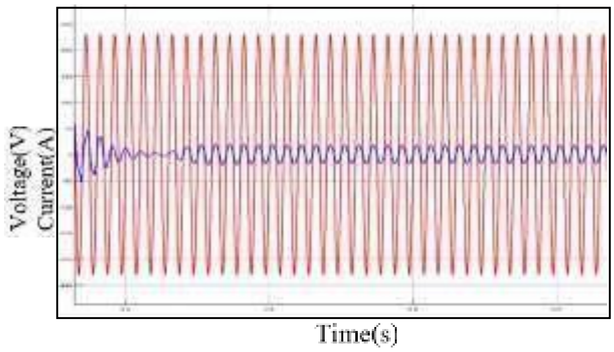

Fig 11: Grid voltage current waveforms.

Phase locked loop is used to set the phase shift between currentand voltage is set to zero. The grid voltage(V_{grid}) is set to 230V and grid current rises upto 18Amps. PI and PR controllers are usedfor controlling the current and voltage of the grid

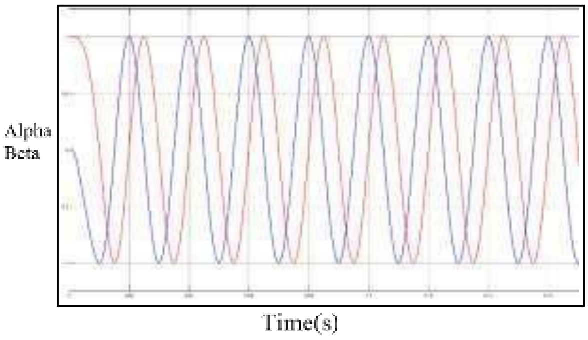

Fig 13: Alpha Beta waveforms.

The alpha and beta each provides a 45^0 phase shift, they are obtained from the grid voltage by using double first order filter. Beta is the actual grid voltage where as Alpha is the phase shifted voltage. These alpha beta voltages are given to the PLL for setting the phase shift between the voltage amd current. The phase betweenalphaand beta is 90^0.

6.Conclusion:

This paper is for integration of PV systemwith the grid and obtaining MPPT by using a combination of converters starting with boost converter that is dc-dc converter, the operation and design of boost converter is discussed. Strategies for controlling the voltage and current usingproportional integral controller and proportionalresonantcontroller while converting DC-AC using voltage source inverter with less harmonics using LCL filter is discussed. Finally a model is designed to integrate PV systemwith single phase grid and output waveforms are analyzed.

References:

[1] Cody A. Hill, Matthew Clayton Such, Dongmei Chen, Juan Gonzalez, and W.Mack Grady, "Battery energystorage for enabling integration of distributed solar power generation", IEEE Trans. on Smart Grid. vol. 3, no. 2, June 2012. *IET Electr. Power Appl.*, vol. 1, no. 5, pp. 643–656, 2007.

[2] Xiaoting Wang, John Byrne, Lado Kurdgelashvili1 & Allen Barnett (2012). Introduction. High efficiency photovoltaics: on the way to becoming a major electricity source. Retrieved from http:// http://ceep.udel.edu/wpcontent/uploads/2013/08/2012_es_WIRE_EnergyEnvironment_high efficiency-solar_xiaoting+jb+lado+barnett.pdfX. Yu, M. R. Starke, L. M. Tolbert, and B. Ozpineci, "Fuel cell power conditioning for electric power applications : a summary," IET Electr. Power Appl., vol. 1, no. 5, pp. 643–656, 2007.

[3] Hao Qian, Jianhui Zhang, Jih-Sheng (Jason) Lai, and Wensong Yu, "A high-efficiency grid tie battery energy storage system," IEEE Trans. Power Electron., vol. 26, no. 3, pp. 886-896, March 2011.

[4] Modelling & Simulation Of PV System With Fuzzy Mppt Based Converter Jyotirmayee Priyadarshini Dept.of electrical engineering International Conference on Recent Innovations in Electrical, Electronics & Communication Engineering - (ICRIEECE).

[5] DC-DC Boost Converter Design for Fast and Accurate MPPT Algorithms in Stand-Alone Photovoltaic System Norazlan Hashim, Zainal Salam, Dalina Johari, Nik Fasdi Nik Ismail, International Journal of Power Electronics and Drive System (IJPEDS).

[6] Takun, Pongsakor, Somyot Kaitwanidvilai, and Chaiyan Jettanasen. "Maximu m power point tracking using fuzzy logic control for photovoltaic systems."Proceedings of International MultiConference of Engineers and Computer Scientists. Hongkong. 2011.

[7] S. S. Mohammed and D. Devaraj, "Fuzzy based maximum power point tracking controller for stand-alone photovoltaic system using MATLAB/Simulink," Int. J. of Appl. Eng. Research, vol. 10, no. 55, pp. 3101-3106, 2015

[8] DC To DC Converter in Maximum Power Point Tracker, V.C. Kotak, Preti Tyagi. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering.

[9] R. Teodorescu, F. Blaabjerg, M. Liserre, U. Borup. A New Control Structure for Grid-Connected PV Inverters with Zero Steady-State Error and Selective Harmonic Compensation, Proc. of APEC'04, Vol. 1, pp. 580-586.

[10] A. K. S. Bhat and F. Dong Tan, "A Unified Approach to Characterization of PWM and Quasi-PWM Switching Converters: Topological Constraints, Classification, and Synthesis," IEEE Trans. Power Electron., vol. 6, no. 4, pp. 719–726, 1991.

[11] D.P. Hohm and M.E. Ropp. Comparative Study of Maximum Power Point Tracking Algorithms Using an Experimental, Programmable, Maximum Power Point Tracking Test Bed, Proc. of Photovoltaic Specialists Conference, 2000, pp.1699 - 1702.

[12] The New Maximum Power Point Tracking Algorithm using ANN-Based Solar PV Systems Hong Hee Lee School of Electrical Engineering, University of Ulsan, Ulsan, Korea hhlee@mail.ulsan.ac.kr Phan Quoc Dzung HCMC University of Technology Ho Chi Minh City, Vietnam pqdung@hcmut.edu.vn Le Dinh Khoa HCMC University of Technology Ho Chi Minh City, Vietnam khoaledinh@hcmut.edu.vn Le Minh Phuong HCMC University of Technology Ho Chi Minh City, Vietnam lmphuong@hcmut.edu.vn Nguyen Truong Dan Vu HCMC University of Technology Ho Chi Minh City, Vietnam ntdanvu@gmail.com