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SIMULATION ON MPPT BASED SOLAR PV STANDALONE SYSTEM

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ABSTRACT: The present work demonstrates the simulation for PV module with the maximum power point tracking (MPPT) control system in standalone mode. The operation of the proposed system is tested with DC loads. The perturb and observed (P&O) algorithm is demonstrated in this system. The DC load is connected with the system and performance has checked under various atmospheric conditions to verify the efficiency and effectiveness of the algorithm under various atmospheric conditions. The system used in simulation comprises of the single module of solar PV (240W). The concept is demonstrated using simulations done in PSIM ® 9.3.4 software.

KEYWORDS

Maximum power point tracking (MPPT), Photovoltaic (PV), Standalone system

1. INTRODUCTION

The global rise in annual energy demand, global warming, and unstable fossil fuel economy are driving the world to shift towards renewable energy sources for a sustainable future. Wind and solar power are the two renewable energy resources that have increasing share in electricity generation due to the ease of availability, mature technology, and comparatively lower costs. The report published by the Government of India (GoI) on 31st May, 2015 states that about 19,706 Indian villages are in need of electrification (Progress Report of Village Electrification, 2016). The main challenges in achieving the target of electrification of a rural country are remote locations far from grid connection, unsuitable terrains, and cost of transmission. Hence, the possible solution lies hidden in renewable energy systems. Most of the parts of India annually experience bright and sunny days for almost 250 to 300 days (Information of Solar RPO, 2016). Moreover, as per the report by Ministry of New and Renewable Energy, GoI, states like Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, and Tamilnadu have high potential to harness the wind energy. Thus, wind energy system (WES) and photovoltaic energy system (PVES) are seen as essential resources to meet the challenge of rural electrification.

If rural electrification is achieved with photovoltaic (PVs), then to keep the area powered up at night time large battery backup would be required. This would increase the cost of energy and may in some cases lead to the solution being economically infeasible. Another possible option therefore, is hybridization with other renewable energy sources.

In recent times, low voltage distribution systems supported by renewable energy systems and other energy storage elements in conjunction with the grid, termed as hybrid energy systems, are preferred to reduce carbon emissions and reliance on fossil fuels (Liu, Wang, & Loh, 2011). The academic and industrial interest in hybrid energy systems is evident from the number

of related literature in recent times (Mendis, Muttaqi, Sayeef, & Perera, 2012; Valenciaga, & Puleston, 2005, Nehrir, LaMeres, Venkataramanan, Gerez, & Alvarado, 2000, Ahmed, Miyatake, & Al-Othman, 2008, Hirose, & Matsuo, 2012; Kumaravel & Ashok, 2015, Eroglu, Dursun, Sevencan, Song, Yazici, & Kilic, 2011). A review of different stand-alone hybrid solar systems for off-grid and rural electrification with load type, design capacity and its outcome is presented in (Mahesh, & Sandhu, 2015).
Off grid systems are reported and reviewed in (Akikur, Saidur, Ping, & Ullah, 2013) Different hybrid standalone systems, such as stand-alone solar PV system, hybrid solar PV wind system, hybrid solar PV diesel system and hybrid solar PV wind diesel systems are also discussed in the review (Akikur et al., 2013). Similarly, Mahesh et al. have presented critical reviews of available hybrid wind-PV with battery backup (Mahesh et al., 2015). Due to wide acceptance of AC supply, the hybrid energy systems were analyzed for AC supply. PVES and BESS provide DC supply, whereas WES or diesel engine systems required AC-DC and then DC-AC conversion. Hence, the AC systems suffer from the increased stage of power conversion, increased power electronics converters and associated losses. DC system can be seen as an alternative where the power conversion stages are reduced. In remote rural locations, the DC supply can feed the LED lighting loads and fan loads. Moreover, many of the consumer electronics convert AC-DC and, in some cases, DC-AC. In addition to this, DC systems have the merits of (i) higher efficiency because of absence of inverter between the DC link and load, (ii) absence of grid synchronization, reactive power management and related issues, and (iii) DC system has inherent fault ride through capability in case of grid connected systems (Kakigano, Miura, & Ise, 2010). Hence, isolated DC energy system with PV installation is an ideal for remote rural electrification. Low voltage hybrid DC system for a residential complex is reported by Hiroaki et al. al.,(2010). DC energy systems with local DC grid involve DC-DC converters to interface the solar or battery system with the point of common coupling. The DC-DC converters regulate the voltage at the point of common coupling and at the same time ensure that the photovoltaic panels are loaded in such a way that the maximum power is drawn. Maximum power point tracking algorithm estimates the current or voltage which when drawn or maintained across from the PV panel ensures that maximum power is delivered. Variations in these conditions can affect not only the DC current and voltage levels of the energy resources but also the system stability. Traditionally, proportional integral (PI) controllers are employed to regulate the DC supply voltage and ensure that the PV is operating at maximum power point.

The power circuit of PV module consists of series connected PV cells, DC-DC converter, and load. The voltage and current sensors are employed to measure the PV voltage (V_{PV}) and PV current (I_{PV}). The PV modules are identified with their wattage capacity as well as other parameters like open circuit voltage (V_{OC}), short circuit current (I_{SC}), rated voltage or maximum power voltage (V_R), rated current (I_R) or MPP. Fig. 1 shows the equivalent circuit of single diode PV which is used in the analysis. This model consists of photo current source, diode, series resistor and parallel resistor. S indicates light intensity (Kollimalla et al., 2013) The series connection of the PV cells will become module and series, or parallel connections of many modules will become an array. The radiation and temperature are measured concerning standard test conditions (STC) with 1000W/m^2 radiation and 25^{0}C temperature of the module as a reference.

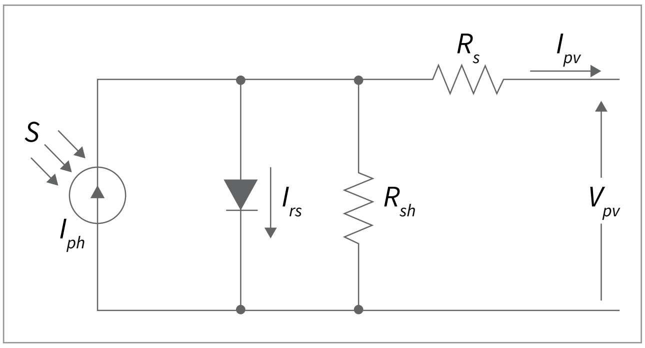

FIGURE 1. Equivalent Circuit of PV Cell

The series connection of these cells will become module and series or parallel connections of a number of modules will become an array. The non-liner IV characteristics of PV cell is given by,

$$I_{PV} = I_{ph} - I_{rs}\left(e^{\frac{q(V_{pv}+I_{pv}R_s)}{AkT}} - 1\right) - \frac{V_{pv}+I_{pv}R_s}{R_{sh}} \qquad (1)$$

Where,
I_{pv} is Output current (A)
I_{ph} is Light generated current or photo current (A)
I_{rs} is Diode reverse saturation current
V_{pv} is Output voltage (V)
q is Electron charge (= 1.609x10^{-19} C)
A is Diode ideality constant
k is Boltzmann's constant (= 1.38x10^{-23} J/K)
T is cell absolute temperature (^{0}K)

Moreover, other parameters of PV module are obtained from Solarex MSX-60 data sheet. Using tutorial file of PSIM the two strings have made by connecting multiple modules in series and parallel as a single panel per string as shown in the block diagram.

2. BRIEF OF SOLAR MPPT ALGORITHMS AND ITS IMPLEMENTATION IN PSIM ® 9.3.4 SOFTWARE

The MPPT algorithms are implemented to the PV modules with boost converters to track the operating point under different varying isolation conditions which could deviate from standard test conditions. These algorithms are used to track the power under different varying radiations. There are various MPPT techniques available in literature. A large number of studies have been done on Incremental conductance method and Perturb and observe method.

P&O method finds the maximum power point of PV modules by means of iteratively perturbing, observing, and comparing the power generated by the PV modules. It is widely applied to the maximum power point tracker of the photovoltaic system for its features of simplicity and convenience.

In majority of the cases perturb and observe (P&O) algorithm and incremental conductance (INC) are used. The P&O algorithm is found to be easy in implementation and used for battery charging applications. In this method, the operating voltage or current of the PV module is perturbed and then the power obtained is observed to decide the direction of further changes in the voltage with change in atmospheric conditions.

If perturbation increases the power, then the voltage or current is kept on changing in the same direction until the power begins to fall. The algorithm measures the instant voltage (V_t) and current (I_t) to calculate the power (P_t) and then compare it with last calculated power (Pt-1). The algorithm continuously perturbs the system if the operating point variation is positive; otherwise, the direction has changed.

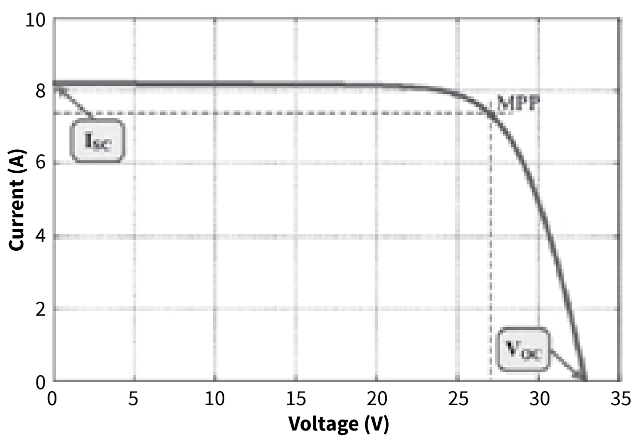

FIGURE 2. PV Current v/s Voltage Characteristic. [18]

3. SYSTEM CONFIGURATION AND BLOCK DIAGRAM

The block diagram of the standalone system is shown in fig. 3. The system comprises of single PV module connected with DC-DC converter. The reference signal is generated from MPPT algorithm and compared with actual current drawn from the PV. The algorithm has been programmed in DLL (Dynamic link library) block, available in PSIM ® 9.3.4 software. Simple PI controller with closed loop has been demonstrated in the same software. The PI controller is tuned for various operating conditions. The change in operating conditions results change in duty cycle of the switch. The efficiency of algorithm is found from superimposing two curves of available power and tracked power from the PV. To check the effectiveness of the algorithm square wave with in specific range of radiation is applied as an input to the PV with 25^0 C of PV temperature. In this simulation the switching frequency is taken as 10 kHz and used for generation of gating pulse. These results are demonstrated in next section.

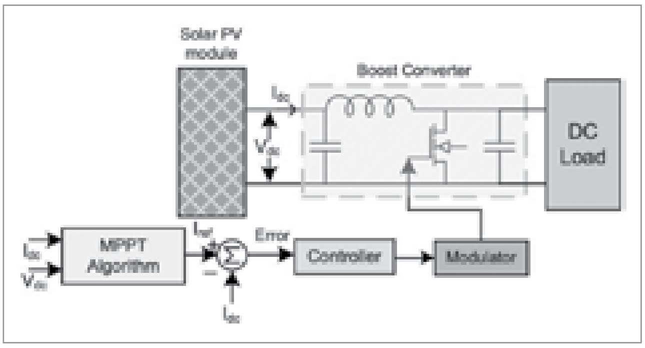

FIGURE 3. Block diagram of PV standalone system

4. SIMULATION OF STANDALONE SYSTEM AND RESULTS

Fig. 4 gives the simulation of solar module used as a power generation with its MPPT; here the single panel of 240W is simulated in PSIM ® 9.3.4 software and results are compared with and without perturbation applied to radiation. The MPPT code has developed in DLL block available in PSIM with visual studio C++. The perturbation is applied to the input of the PV panel using square wave input within the specific range of radiation. The closed loop DC-DC converter is used in boost mode to maintain constant voltage within the specific range of load. The calculation of inductor and capacitor for this specific work has done using equations available in Michael Green (2012). Further, the generated power from PV (P_{max} in simulation) is compared with actual power (Power) which can be further used for the measurement of the efficiency of the algorithm. In fig. 4 complete simulation circuit is shown. The current perturbation algorithm is used in this work proposed in Kollimalla & Mishra (2014). The MPPT algorithm generated the reference current and compared with the actual current depending upon the short circuit current. This current is compared with actual PV current generated by the module. PI controller is fine tune with specific limits and the gate pulse is generated.

Fig. 5 and fig. 6 shows the response of the system when the perturbation is applied to the radiation. After applying perturbation on solar PV module, MPPT efficiency is measured by superimposing two curves of maximum available power (named P_{max} in fig. 5) and tracked power (named Power in fig. 5). This can be done at different radiations. Similarly, results may be obtained with changing in loads as well as module temperature. Fig. 7 shows actual power consumed at various radiation levels.

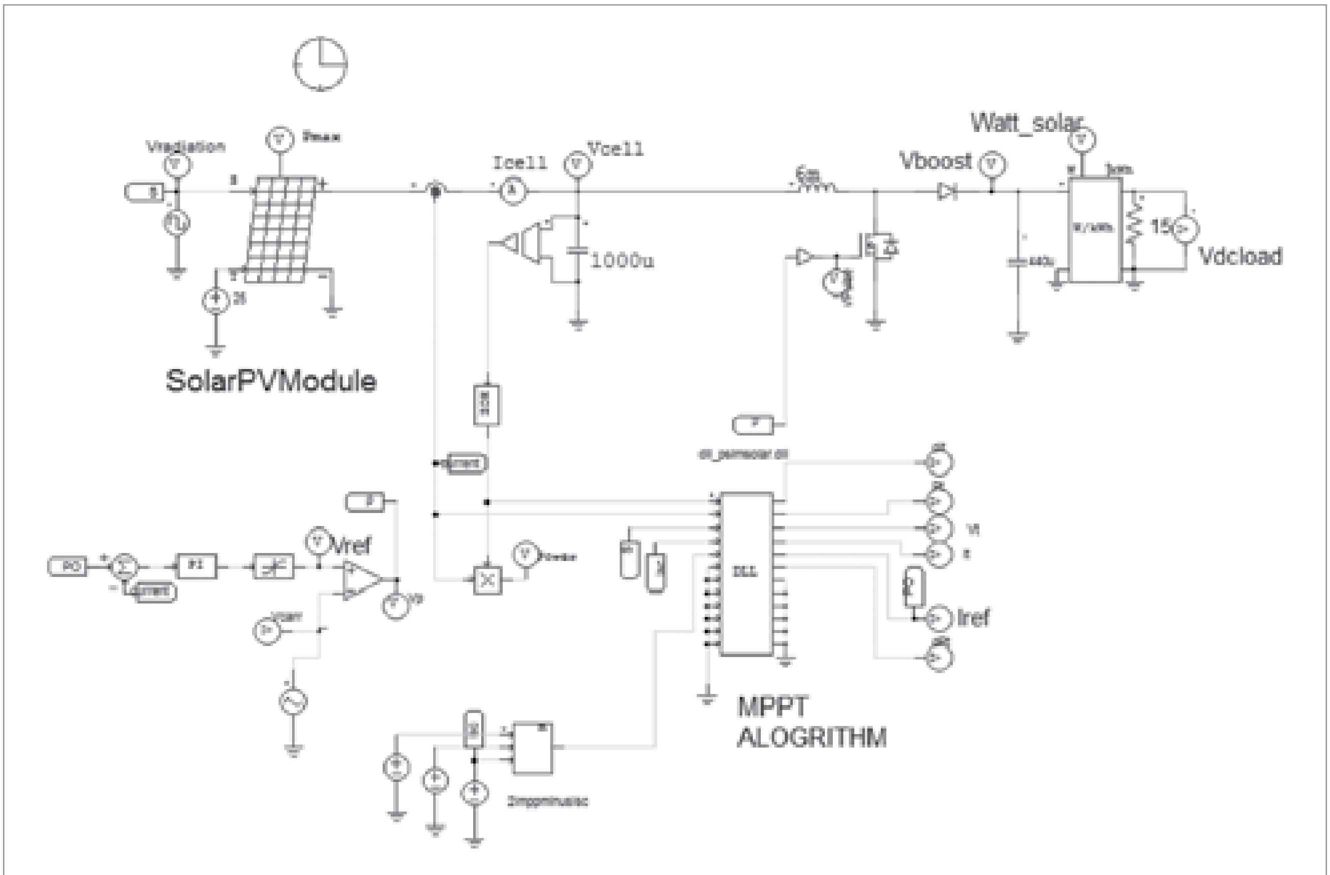

FIGURE 4. PSIM based simulation circuit with P&O MPPT Algorithm - Single PV Module

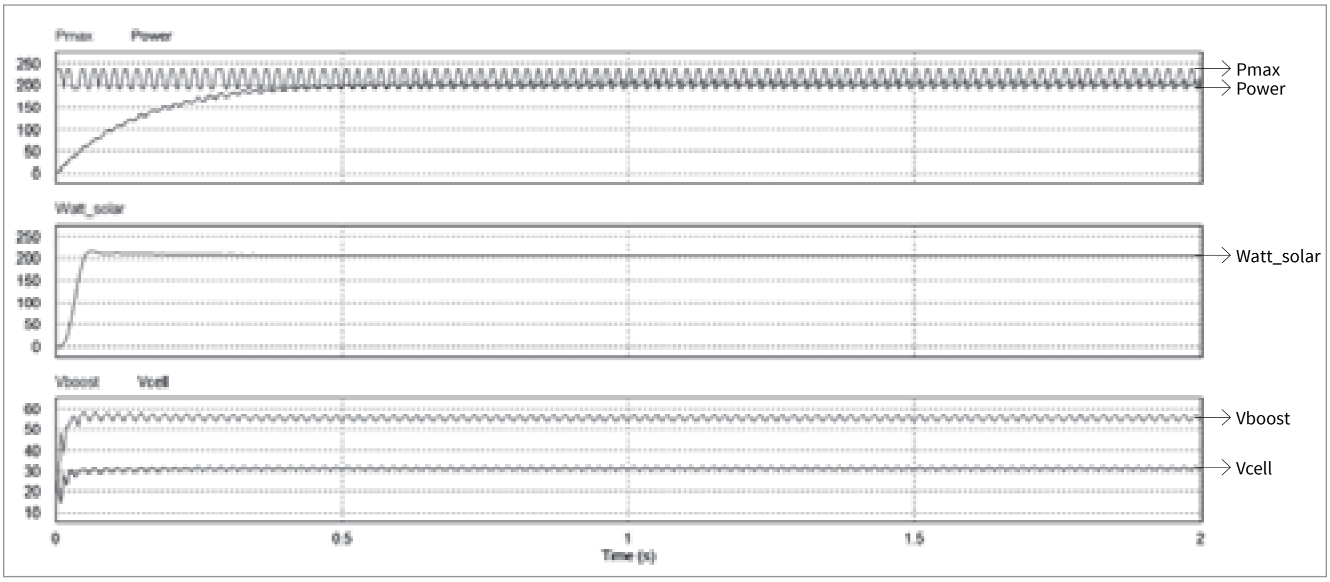

FIGURE 5. Result of Maximum Power from PV (P_{max}), Power Consumed by Load (Watt_Solar), Tracked Power (Power) and Response of Boost Converter at Constant Radiation. (MPPT Efficiency 86.91%)

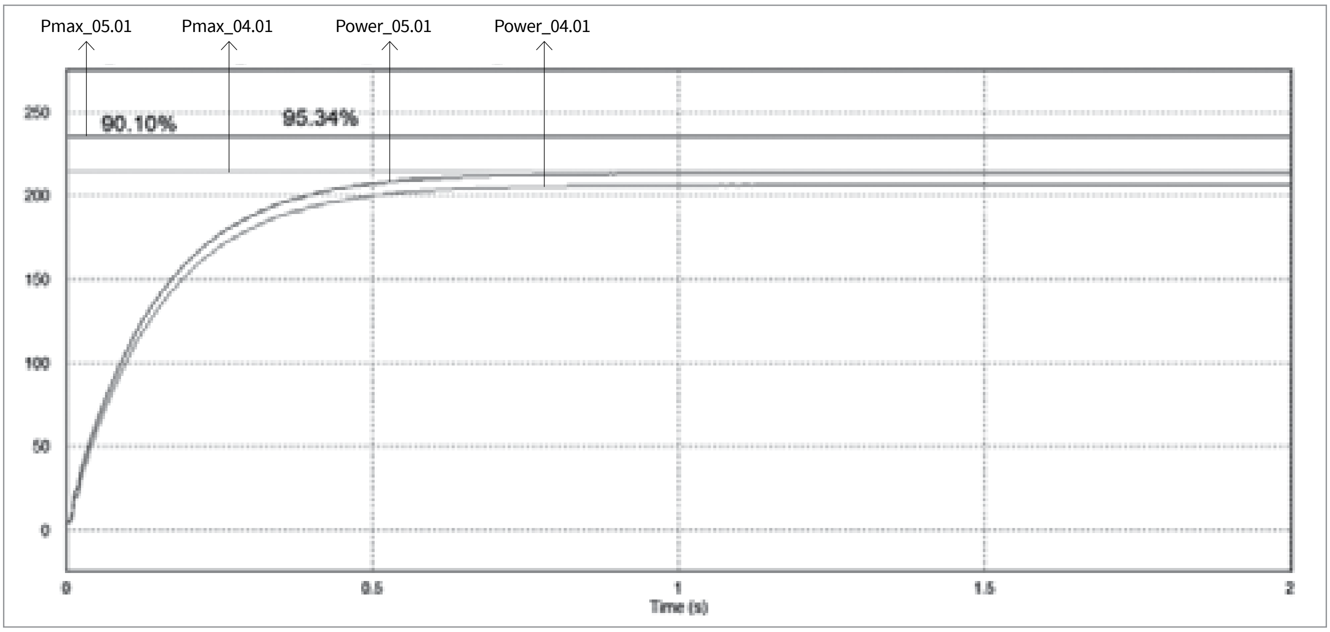

FIGURE 6. Maximum power and tracked power at different radiation with its efficiency

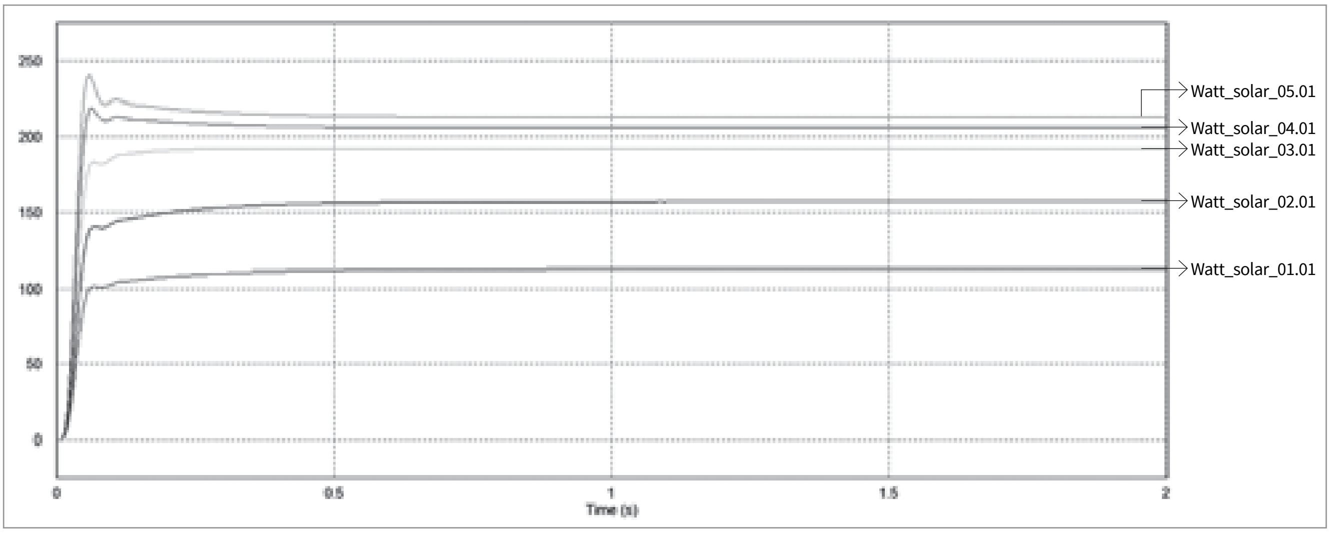

FIGURE 7. Actual power consumed at different radiations by wattmeter

Then the same results are demonstrated and verified for 30 such 60W each module connected in series and comparison was done with MPPT algorithm and without MPPT algorithm. Fig. 8(a) and (b) are showing the comparison of actual power and tracked power with and without MPPT algorithm. The MPPT efficiency is observed at 90%.

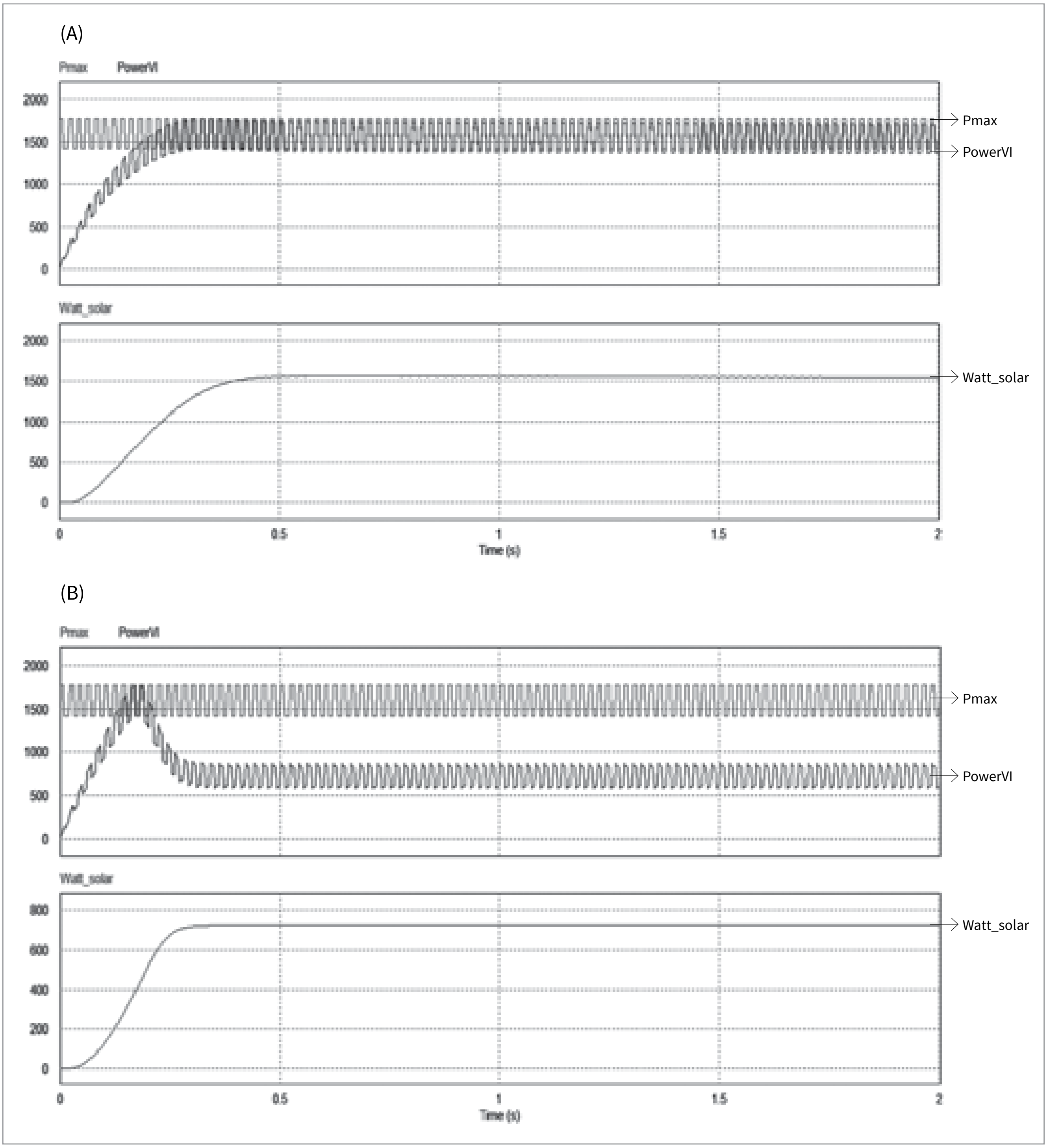

FIGURE 8. Comparison of Maximum Power (P_{max}), Tracked Power (PowerVI) and Consumed Power by Load (Watt_Solar) (A) with and (B) Without MPPT Algorithm.

5. CONCLUSION

The simulation for solar PV with MPPT has demonstrated, that maximum power is tracked with different atmospheric conditions and observing MPPT efficiency at various radiation levels taking current as perturbing variable. For variable perturbation in radiation around STC, the MPPT efficiency is found near about 90% on an average. Moreover if still the load demand is increased one can install more number of modules in series as well as parallel depending upon demand.

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