Design and Analysis of Maximum Power Point Tracking (MPPT) Controller for PV System

Muhammad Yousaf Ali Khan, Faheem Khan, Hamayun Khan, Sheeraz Ahmed, Mukhtar Ahmad

Abstract

With the passage of time, the demand of electricity is increasing day by day. The conventional electricity resources are getting depleted because of limited reserves of coal, natural gas and oil. Also most of the electricity resources are not environmental friendly. There was a need to design a mechanism that can be used as an alternative resource for the production of electricity that can be environmental friendly as well as a cheap source of generation. In the last couple of years, it is indicated that energy obtained from the sun can be the best alternate resource for energy.

In this research work, the system design approach based on the Maximum Power Point Tracking (MPPT) Controller has been designed. This approach is utilized for extracting maximum available power from PV module through simulation in protius software. This system is quite efficient, effective and has high performances. Buck and boost converter have been utilized for better efficiency.

Keywords: Electricity; Renewable Energy; Solar Charge Controller; Maximum Power Point Tracking

I. Introduction

Electricity is considered and is defined as one of our key need and it is analyzed that with the passage of time the demand of the energy is dynamically increasing throughout the globe [xii]. With the passage of time, there is a number of new techniques (Coal power generation, Thermal power generations, Nuclear power generation and many others) that has been invented and developed for the production, generation and distribution of electricity as mentioned in [iii]. However, it is indicated that during the development of the solution for the generation of electricity the
economic strategy is always considered and the stakeholder prefers to utilized that technology that is overall economical and their duration of operations as long as mentioned in [xix].

According to our analysis based on the existing researchers [vi, xx], it is observed that the renewable energy production methods have gained much attention. Renewable energy mechanism is defined as the concept in which the energy is calculated from renewable resources and it is observed that these sources are naturally replenished on a human timescale [iv]. It is analyzed that based on the analysis it is observed that there is much renewable energy that includes geothermal heat, wind, rain, tides etc. but it is observed that more of the stakeholder have preferred to utilize the sunlight for the production and generation of electricity as mentioned in [xvi].

However, it is observed that technically developing the solar system that works through the principles of renewable energy utilization is not considered as the complex task [ii]. But, on the other side it is analyzed that technical with the passage of time there is a number of improvements that has been making in the context of the system. In this research work, we will be presenting the system design approach for the Maximum Power Point Tracking (MPPT) solar charge controller. It is indicated that proposed system design that will be presented in the context of this research is to control and manage the drain of the Solar panel and it is observed that in order to make this process we have utilized the MPPT (Maximum Power Point Tracker). It is observed that the key purpose of the developing of this solution or mechanism is to drain the maximum power from the Solar panel and give it to the output. According to our analysis and understanding, it is indicated that the outcome will be improved and the efficiency of the system can also be ensured.

It is observed that the key theme that has been set for the context of this research work is to design, develop and implement a Maximum Power Point Tracking (MPPT) Solar Charge Controller. It is indicated that the key objective that we will be focusing will be defined as measuring the parameters difference such as solar panels, voltage and current resolution, control and managing the Stepping up and down power such as volt and amp, developing to the component of show the power display, developing the mechanism to reduce the cost and increasing the efficiency of PV array.

In section II, the discussion within the context of literature review has been presented and we will be analyzing the related researchers within the context of Maximum Power Point Tracking (MPPT) and also will be analyzing the solar charge controller.

In section III, the system design and implementation will be presented and this chapter we will also be discussing the algorithm. In the system selection, the proposed solution will be tested. The last two sections of the paper, the conclusion and recommendation have been presented.

II. Literature Review

Renewable energy is considered as one of the most discussed topics and it is observed that through the utilization of the renewable resources there is a high
probability that need of the energy can be fulfilled if these resources are properly managed and are converted properly. It is observed that with the passage of time there are different types of techniques that have been developed for the conversion of the energy and it is indicated that more of these techniques are utilized in the real-time environment. However, according to our analysis in the context of this research, we will be analyzing these techniques and will be identifying that how the Maximum Power Point Tracking (MPPT) can fit best according to the solar charge controller.

During the analysis, it is indicated that there are several strategies that can be considered in the context to optimize the power output of an array as mentioned in [ii, ix, x]. During the analysis, it is indicated that different algorithms and switch has been set so that the operating conditions of the array can be executed.

A. Perturb and Observe

This method is utilized to adjust the voltage in a small amount through the utilization of the array and measure the power [viii]. This research work also analyzed that if the power increases further adjustments can also be integrated into the context of until no power is increased [x]. According to the analysis, it is defined as perturbing and observes method and it is indicated that through the utilization of this method results in oscillations of power output can be achieved. According to our analysis basedon the existing researchers [i, xvii], it is indicated that this algorithm or strategy can be integrated into the context of Maximum Power Point Tracking.

B. Incremental conductance

The incremental conductance method helps in controlling and managing the measure incremental changes in PV array [xi]. It is observed that the array of current and voltage is utilized to predict the effect of a voltage change. However, it is indicated that this method required more computation in control and they have the capacity to track changing conditions as mentioned in [i]. It is indicated that the Incremental conductance is quicker as compared to the perturb and observe method (P&O) but it is indicated that they required high resources for computing that is considered as the key reason that most of the system is not equipped with Incremental conductance [xiv].

C. Current sweep

According to our analysis basedon the existing researchers [xiv, vii], it is indicated that current sweep method is not commonly utilized. It is indicated that in simple these methods utilized PV array and continuously obtained and update fixed time interval. It is indicated that sweep waveform for the PV array current is utilized in the context of this methodology as indicated by [xxii]. It is also indicated that the MPPV can compute from the characteristic curve at the same intervals.

Based on the above discussion it is suggested that Perturb and Observe will be utilized as this method is easy to deploy and there is a high probability that better results and the drain can be minimized. On the other side, it is also observed that it required less computation as compared to the Current sweep and Incremental conductance. So, in this research, we will be using this method. In the next section system design and implementation related to Maximum Power Point Tracking
(MPPT) Solar Charge Controller is presented.

III. System Design and Implementation

The system architecture is defined as the conceptual frameworks that define the structure, behavior, and more views of a system [xiii]. According to our analysis, it is observed that in this section we will be presenting the structure, behavior, and more views of a Maximum Power Point Tracking (MPPT).

In system architecture, it can be observed that PV has been utilized as the input mechanism that takes the input from the sunlight. However, it is observed that one of the challenging processes in the context of the solar system are the store the energy. It is observed that in the context of the proposed solution we have to utilize the battery. It is indicated that the key purpose of the battery is to store the agent. However, we have also utilized the MPPR charge controller that is developed by Leonics for series of SPT. As indicated in the figure 1 it is observed that the MPPT charge controller will be connected with the four components including PV, Battery and the DC load and the inverter.

It is indicated that we will also be putting the inverter and the inventor will be connected with the AC load. Based on the deep understanding through the integration of the Maximum Power Point Tracking (MPPT), it is observed that there is a high probability that charge will overall be improved and the better outcome can be executed. According to our understanding, it is observed that it is a simple process and with the passage of time new techniques can be added. In the block structure more explanation of the proposed solution has been presented.

According to the proposed architecture, it is observed that we have integrated the MPPT charge controller and within the Maximum Power Point Tracking charge controller, the Buck-Boost converters have been added.
A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load) as shown in Fig.2. Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators. Buck converters can be remarkably efficient (often higher than 90%).

![Buck Converter block diagram of MPPT](image)

**Fig. 2 Buck Converter block diagram of MPPT**

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load) as shown in Fig.3. The boost converter is a DC to DC converter with an output voltage greater than source.

![Boost Converter block diagram of MPPT](image)

**Fig.3 Boost Converter block diagram of MPPT**

It can also be observed that we have integrated CS and VS components that will be linked with the battery. It is also indicated that the drain would also be minimized if
the proposed algorithm is properly integrated. It is indicated in the context of the proposed solution the Cuckoo Search (CS) method has also been integrated so that MPPT option, a comprehensive assessment is carried out against two well-established methods, namely Perturbed and Observed (P&O) and Particle Swarm Optimization (PSO). The protius simulation is shown in Fig. 4.

![Block diagram Protious Simulation of MPPT](image)

**Fig.4 Block diagram Protious Simulation of MPPT**

**D. Optimization**

According to our analysis, it is indicated that one of the key aspects of the proposed solution is the optimization. It is indicated that on the 12-volts PV panels are designed to provide an output of 16 to 18 volts and based on the analysis it is observed that lost about 48 watts will be reporting. However, through the implementation of the Maximum Power Point Tracking, it can be indicated that overall the loss rate would directly decrease and the better outcome can be obtained.

During the analysis, it is indicated that there are different types of an algorithm that can be utilized for the Maximum Power Point Tracking Algorithms and in the context of this research we will be using the P&O and the InCond algorithms that are mostly utilized in Maximum Power Point Tracking. In the context of this research we have utilized the Hill-climbing technique and through the help of this technique it is observed that it allows the operation point of the PV array in the direction in which power increases. However, based on the existing researchers [xxiii, xv] it is observed that this technique is easy to implement and overall the performance is quite well as compared to the other techniques that have been provided for the same purpose as mentioned in [xviii, xxvi].
It is observed that the P&O Algorithm as shown in Fig.5. has been presented that will be implemented in the context of the proposed solution. It can be observed that in the context of the proposed solution there are multi decision-making processes that have been integrating to obtain the outcome. In the next section, the verification and validation of the proposed solution (Maximum Power Point Tracking (MPPT) Solar Charge Controller) have been conducted.

IV. Conclusion

Testing of any sort of system is always defined as one of the complex, critical and time-consuming processes. However, in order to test the proposed solution, we have indicated that instead of testing the proposed solution in real time environment we will be using the simulation environment so that each parameter of the Maximum Power Point Tracking (MPPT) Solar Charge Controller can be tested and the can be identified that what are the key parameters that need to be improved as shown in Fig.6. According to our analysis, it is observed that if the testing results are positive the proposed solution will be integrated into the context of real-time environment.
The P&O algorithm is also called “hill-climbing”, but both names refer to the same algorithm depending on how it is implemented. Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O a perturbation in the operating voltage of the DC link between the PV array and the power converter. In the case of the Hill-climbing, perturbing the duty cycle of the power converter implies modifying the voltage of the DC link between the PV array and the power converter, so both names refer to the same technique.

In this method, the sign of the last perturbation and the sign of the last increment in the power is used to decide what the next perturbation should be. As can be seen in Figure 6, on the left of the MPP incrementing the voltage increases the power whereas on the right decrementing the voltage increases the power.

If there is an increment in the power, the perturbation should be kept in the same direction and if the power decreases, then the next perturbation should be in the opposite direction. Based on these facts, the algorithm is implemented. The process is repeated until the MPPT is reached.
It is observed that this experiment has been conducted to measure the system response time which has been measured in context of traditional system that is most deployed in the region of Pakistan as shown in Fig.7. According to our analysis, it is indicated that proposed solution has better results as compared to the traditional system especially when compared in the context of system response time. In the next section, the conclusion has been presented.

In the end, the proposed solution is quite efficient and effective. According to our analysis, it is observed that the results that are being calculated from the proposed solution have indicated that the proposed solution can be deployed in the real-time environment. The system design approach has utilized the Maximum Power Point Tracking as solar electric charge controllers and it is observed that this proposed solution has overall helped us in controlling and managing the drain of the Solar panel and directly has helped in increasing the performances. During the analysis it is has been indicated the Maximum Power Point Tracking scheme is more effective in Cold weather, Low battery charge and Long wire runs.

Based on the deep analysis and understanding it is observed that proposed solution can be deployed in real time environment and it is indicated that there is a high chance the through the deployment of the proposed solution that electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid can be utilized. According to our analysis and understanding, it is suggested that the Smart power trackers can also be linked within the context of Maximum Power Point Tracking (MPPT) Solar Charge Controller so that the better outcome can be extracted.

In the next section, the key recommendation has been provided within the context of Maximum Power Point Tracking (MPPT) Solar Charge Controller. It is indicated that there is a high chance that if the key recommendation is followed better results can be obtained.
V. Recommendation

According to our analysis it is observed that there is always a room for implementation and based on the existing researchers [iv, xxii, xxv] it is observed that if the following recommendation is followed there is a high probability that better solution in context of Maximum Power Point Tracking (MPPT) Solar Charge Controller can be presented:

1) Intelligent and Multi Parameters

a. It is observed that during the development of the proposed solution we have only considered standard parameters. However, it is suggested that Intelligent and Multi Parameters need to be integrated into the context of the proposed solution. According to the existing researchers, it is observed that if the parameters are not properly managed there is a high chance that the key results and the efficiency of the system will be improved.

2) Mainstream Technologies

a. During the investigation, it is analyzed that there are different types of mainstream technologies such as geothermal energy, Bio-energy, Energy storage and many other. However, based on the research result it is indicated that we have only targeted the solar energy. So, it is suggested that more works need to be conducted in the context of developing the solution for more mainstream technologies.

3) Communication Strategy

a. It is observed that communication strategy need to be developed during the proposed solution. It is indicated that if the proper communication is developed there is a high probability that better results and outcome can be obtained. On the other side, it is observed that the decision making will be improved supporting the argument from [v].

E. Impact of Recommendation

It is observed that in the table I the impact of the recommendation has been provided.

| Recommendation                  | Impact    |
|---------------------------------|-----------|
| 1 Intelligent and Multi Parameters | High      |
| 2 Mainstream Technologies       | High      |
| 3 Communication Strategy        | Medium    |
In the end, it can be summarized that if the above recommendation is properly followed and implemented during the design, development and implementation of Maximum Power Point Tracking (MPPT) Solar Charge Controller there is a high chance the better results and the performance can be achieved.

References

I. A. Ali, Y. Wang, W. Li and X. He, “Implementation of simple moving voltage average technique with direct control incremental conductance method to optimize the efficiency of DC microgrid,” in Emerging Technologies (ICET), 2015 International Conference on, 2015.

II. A. Argentiero, C. A. Bollino, S. Micheli and C. Zopounidis, “Renewable energy sources policies in a Bayesian DSGE model,” Renewable Energy, vol. 120, pp. 60-68, 2018.

III. A. Naserbegi, M. Aghaie, A. Minuchehr and G. Alahyarizadeh, “A novel exergy optimization of Bushehr nuclear power plant by Gravitational Search Algorithm (GSA),” Energy, 2018.

IV. A. Soetedjo, A. Lomi and B. J. Puspita, “A Hardware Testbed of Grid-Connected Wind-Solar Power System,” International Journal of Smart Grid and Sustainable Energy Technologies, vol. 1, pp. 52-56, 2018.

V. A. M. Atallah, A. Y. Abdelaziz and R. S. Jumaah, “Implementation of perturb and observe MPPT of PV system with direct control method using buck and buck-boost converters,” Emerging Trends in Electrical, Electronics & Instrumentation Engineering: An international Journal (EEIEJ), vol. 1, pp. 31-44, 2014.

VI. B. Gjorgiev and G. Sansavini, “Electrical power generation under policy constrained water-energy nexus,” Applied Energy, vol. 210, pp. 568-579, 2018.

VII. F. Zhou, Y.-F. Chang, B. Fowler, K. Byun and J. C. Lee, “Stabilization of multiple resistance levels by current-sweep in SiOx-based resistive switching memory,” Applied Physics Letters, vol. 106, p. 063508, 2015.

VIII. J. Ahmed and Z. Salam, “An improved perturb and observe (P&O) maximum power point tracking (MPPT) algorithm for higher efficiency,” Applied Energy, vol. 150, pp. 97-108, 2015.

IX. K. Khanafer and K. Vafai, “A review on the applications of nanofluids in solar energy field,” Renewable Energy, 2018.
X. K. Ishaque, Z. Salam and G. Lauss, “The performance of perturb and observe and incremental conductance maximum power point tracking method under dynamic weather conditions,” Applied Energy, vol. 119, pp. 228-236, 2014.

XI. K. S. Tey and S. Mekhilef, “Modified incremental conductance MPPT algorithm to mitigate inaccurate responses under fast-changing solar irradiation level,” Solar Energy, vol. 101, pp. 333-342, 2014.

XII. L.-L. Li, G.-Q. Lin, M.-L. Tseng, K. Tan and M. K. Lim, “A Maximum Power Point Tracking Method for PV System with Improved Gravitational Search Algorithm,” Applied Soft Computing, 2018.

XIII. M. Peng, Y. Li, Z. Zhao and C. Wang, “System architecture and key technologies for 5G heterogeneous cloud radio access networks,” IEEE network, vol. 29, pp. 6-14, 2015.

XIV. P. Sivakumar, A. A. Kader, Y. Kaliavaradhan and M. Arutchelvi, “Analysis and enhancement of PV efficiency with incremental conductance MPPT technique under non-linear loading conditions,” Renewable Energy, vol. 81, pp. 543-550, 2015.

XV. P. Ghamisi and J. A. Benediktsson, “Feature selection based on hybridization of genetic algorithm and particle swarm optimization,” IEEE Geoscience and Remote Sensing Letters, vol. 12, pp. 309-313, 2015.

XVI. R. Kardooni, S. B. Yusoff, F. B. Kari and L. Moeenizadeh, “Public opinion on renewable energy technologies and climate change in Peninsular Malaysia,” Renewable Energy, vol. 116, pp. 659-668, 2018.

XVII. R. M. Linus and P. Damodharan, “Maximum power point tracking method using a modified perturb and observe algorithm for grid connected wind energy conversion systems,” IET Renewable Power Generation, vol. 9, pp. 682-689, 2015.

XVIII. R. Cheng and Y. Jin, “A social learning particle swarm optimization algorithm for scalable optimization,” Information Sciences, vol. 291, pp. 43-60, 2015.

XIX. S. Dincer and I. Dincer, “Comparative Evaluation of Possible Desalination Options With Various Nuclear Power Plants,” in Exergetic, Energetic and Environmental Dimensions, Elsevier, 2018, pp. 569-582.

XX. S. Krauter, “Simple and effective methods to match photovoltaic power generation to the grid load profile for a PV based energy system,” Solar Energy, vol. 159, pp. 768-776, 2018.

XXI. S. Carley, “State renewable energy electricity policies: An empirical evaluation of effectiveness,” Energy policy, vol. 37, pp. 3071-3081, 2009.
XXII. S. P. Ayeng’o, T. Schirmer, K.-P. Kairies, H. Axelsen and D. U. Sauer, “Comparison of off-grid power supply systems using lead-acid and lithium-ion batteries,” Solar Energy, vol. 162, pp. 140-152, 2018.

XXIII. S. Kiranyaz, T. Ince and M. Gabbouj, “Particle swarm optimization,” in Multidimensional Particle Swarm Optimization for Machine Learning and Pattern Recognition, Springer, 2014, pp. 45-82.

XXIV. T. Esram and P. L. Chapman, “Comparison of photovoltaic array maximum power point tracking techniques,” IEEE Transactions on energy conversion, vol. 22, pp. 439-449, 2007.

XXV. V. Salas, E. Olias, A. Barrado and A. Lazaro, “Review of the maximum power point tracking algorithms for stand-alone photovoltaic systems,” Solar energy materials and solar cells, vol. 90, pp. 1555-1578, 2006.

XXVI. Y. Shi and R. C. Eberhart, “Fuzzy adaptive particle swarm optimization,” in Evolutionary Computation, 2001. Proceedings of the 2001 Congress on, 2001.