Performance Analysis of PV based Low Power Multi-Core Embedded Management using Wireless Communication System

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Abstract – This paper proposed to improved Quality of Service and cost reduction are important issues affecting the telecommunication industry. Companies such as Airtel, Gio etc believe that the solar powered cellular base stations are capable of transforming the communication industry due to their low cost, reliability, and environmental friendliness. Currently, there is several research efforts directed on the use of solar power in the telecommunication industry. In this paper, the importance of solar energy as a renewable energy source for cellular base stations is analyzed. Also, simulation software proteus is used to obtain an estimate of the cost of generation of solar power for cellular base stations. With this we introduce MPPT for efficient charging.

Index Terms – DC-DC Converter, Fuzzy Control, Maximum Power Point Tracking (MPPT) algorithm, Photovoltaic (PV) Cells, Power Management, Wireless Transmission.

1. INTRODUCTION

Cellular communications technologies such as handsets and base stations have become very common technologies throughout the developing and developed world. Roughly three billion users spend large portions of their income on these communication technologies. However, the remaining half of the world currently has limited access, in large part due to lack of network coverage. Some areas do not have a high enough population density to support a traditional cellular deployment. Other areas are too far from established infrastructure to make a deployment economically possible. This is why there are many rural areas where there is no network coverage at all. Mobile telecom networks require an enormous amount of power.

In markets with unreliable grid power, this energy often comes from diesel fuel. By some estimates, some country like Nigeria alone already uses well over 150 million liters of diesel fuel every year to power telecom base stations when the grid power is not present or not available. This does not include the fuel needed to transport fuel to the mobile sites. Adding several base-stations for rural users can only multiply this destructive environmental impact, unless these base-stations are supported by a sustainable alternative. Running mobile phone networks is getting more expensive and difficult, due to increasing energy costs in developing countries and as operators increase the number of base stations in the infrastructure, so that they can offer third generation networks, wireless services at broadband data rates, power consumption is set to continue to rise.

2. RELATED WORK - PV MODELLING WITH MPPT TRACKING

2.1 Variable Step Size Maximum Power Point Tracker Using a Single Variable for Stand-alone Battery Storage PV Systems:

The subject of variable step size maximum power point tracking (MPPT) algorithms has been addressed in the literature. However, most of the addressed algorithms tune the variable step size according to two variables: the photovoltaic (PV) array voltage (V_{PV}) and the PV array current (I_{PV}). Therefore, both the PV array current and voltage have to be measured. Recently, maximum power point trackers that are based on a single variable (I_{PV} or V_{PV}) have received a great deal of attention due to their simplicity and ease of implementation, when compared to other tracking techniques.

In this paper, two methods have been proposed to design a variable step size MPPT algorithm using only a single current sensor for stand-alone battery storage PV systems. These methods utilize only the relationship between the PV array measured current and the converter duty cycle (D) to automatically adapt the step change in the duty cycle to reach the maximum power point (MPP) of the PV array. Detailed analyses and flowcharts of the proposed methods are included. Moreover, a comparison has been made between the proposed methods to investigate their performance in the transient and steady states [1-10].

2.2 Comparison Study of Maximum Power Point Tracker Techniques for PV Systems:

These techniques vary in many aspects as simplicity, digital or analogical implementation, sensor required, convergence speed, range of effectiveness, implementation hardware, popularity, cost and in other aspects. This paper presents in details comparative study between two most popular algorithms technique which is incremental conductance algorithm and perturb and observe algorithm. Three different converter buck, boost and cuk converter use for comparative in this study. Few comparisons such as efficiency, voltage, current and power output for each different combination has been recorded. Multi changes in irradiance, temperature by keeping voltage and current as main sensed parameter been done in the simulation. Matlab Simulink tools have been used for performance evaluation on energy point. Simulation will consider different solar irradiance and temperature variations [11-20].

2.3 A Review of Single-Phase Grid-Connected Inverters for Photovoltaic Modules:

This focuses on inverter technologies for connecting photovoltaic (PV) modules to a single-phase grid [21-25]. The inverters are categorized into four classifications: (i) the number of power processing stages in cascade; (ii) the type of power decoupling between the PV module(s) and the single-phase grid; (iii) whether they utilizes a transformer (either line or high frequency) or not; and (iv) the type of grid-connected power stage. Various inverter topologies are presented, compared, and evaluated against demands, lifetime, component ratings, and cost. Finally, some of the topologies are pointed out as the best candidates for either single PV module or multiple PV module applications.

2.4 On-Line Dead-Time Compensation Technique for Open-Loop PWM-VSI Drives:

A new on-line dead-time compensation technique for low-cost open-loop pulse width modulation voltage-source inverter (PWM-VSI) drives is presented [26-35]. Because of the growing numbers of open-loop drives operating in the low-speed region, the synthesis of accurate output voltages has become an important issue where low-cost implementation plays an important role. The so-called average dead-time compensation techniques rely on two basic parameters to compensate for this effect: the magnitude of the volt seconds lost during each PWM cycle and the direction of the current.

In a low-cost implementation, it is impractical to attempt an on-line measurement of the volt-seconds error introduced in each cycle-instead an off-line measurement is favored. On the other hand, the detection of the current direction must be done on line. This becomes increasingly difficult at lower frequencies and around the zero crossings, leading to erroneous compensation and voltage distortion. This project presents a simple and cost-effective solution to this problem by using an instantaneous back calculation of the phase angle of the current. Given the closed-loop characteristic of the back calculation, the zero crossing of the current is accurately obtained, thus allowing for a better dead-time compensation. Experimental results validating the proposed method are presented [36-51].

3. PROPOSED MODELLING

The next step in the wireless revolution is the connection of everyday devices through wireless technology (so-called embedded wireless). This technology is expected to explode in the next decade, and touch nearly every market sector from personal electronics and medical devices, to transportation infrastructure and manufacturing. Next-generation embedded wireless devices have unique requirements that demand a holistic approach to their design. Their form factor, cost and power consumption must be dramatically lower than existing cellular phones. The design of these devices requires a unique interdisciplinary background in systems, software, hardware and communication theory. The Master of Advanced Study in Wireless Embedded Systems offers a new interdisciplinary education paradigm, designed to provide high-level training for professional engineers who plan to become technical leaders in this burgeoning field.

3.1 Wireless Technologies for Industrial Automation:

The evolution in wireless technologies has opened the door to a new class of plant automation architecture that offers adopters a significant strategic advantage. Driven by substantial and measurable cost savings in engineering, installation, and logistics, as well as dramatic improvements in the frequency and reliability of field data collection, automation experts and IT professionals are presented with an opportunity to deliver a major, positive impact to the bottom line.

Cost benefits are the most intuitive among what’s driving adoption of wireless technologies. Other important considerations are safety and better management of legacy assets not previously on the network. Advantages include the following:

- *Installation savings:* Installation of wirelessly connected assets is up to 10 times cheaper than the wired alterative and offers much faster start-ups and accelerated profits. Engineering costs are dramatically reduced as extensive surveys and planning are no longer required to route wire back to junction boxes or control rooms. The reduced costs in wiring engineering, installation, and maintenance combined with the increased data gathering flexibility is the primary driver for wireless migration.
- *Better information:* Replacing manual readings with automated measurement results in information that is more accurate, timely, and consistent.
- Economy of scale: Deploying additional points in a network is incremental and may include integration onto legacy systems.
- *Operational savings:* Quickly diagnose and troubleshoot plant operations and support predictive maintenance programs by monitoring facility assets. Additionally, identify costly problems leading to excess use of energy or raw materials.

- *Safer operations:* Wireless technologies can reduce human exposure to hazardous environments [when the prior alternative was to send someone to take a reading or manually actuate a valve, for example]. Also, more frequent measurements and early detection of issues can help reduce or even prevent incidents or accidents.

Unfortunately, no one type of wireless technology solves all problems. Therefore, to maximize the return on industrial wireless networking investments, companies select the best technology for a given application. By evaluating attributes of various wireless technologies, essential technology decisions can be made guaranteeing successful implementation of a wireless architecture solution. These attributes include the radio frequency (RF) technology, security, interference rejection, sensitivity, power management, and the ability to embedded wireless into existing original equipment manufacturer (OEM) technologies. Furthermore, those working on the implementation need to determine if new systems should interface with existing systems to preserve [or extend functionality of investments in existing infrastructure. Another consideration is to examine the radio provider's commitment to backward compatibility, which extends the life of a wireless system and lowers lifetime implementation costs.

3.2 Maximum Power Point Tracking:

MPPT or Maximum Power Point Tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage). Maximum power varies with solar radiation, ambient temperature and solar cell temperature.

Typical PV module produces power with maximum power voltage of around 17 V when measured at a cell temperature of 25°C, it can drop to around 15 V on a very hot day and it can also rise to 18 V on a very cold day. Maximum power point tracking (MPPT) is a technique that grid connected inverters, solar battery chargers and similar devices use to get the maximum possible power from one or more photovoltaic devices, typically solar panels, though optical power transmission systems can benefit from similar technology. Solar cells have a complex relationship between solar irradiation, temperature and total resistance that produces a non-linear output efficiency which can be analyzed based on the I-V curve.

It is the purpose of the MPPT system to sample the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental conditions. MPPT devices are typically integrated into an electric power converter system that provides voltage or current conversion, filtering, and regulation for driving various loads, including power grids, batteries, or motors.

3.3 Working of MPPT:

The major principle of MPPT is to extract the maximum available power from PV module by making them operate at the most efficient voltage (maximum power point). That is to say: MPPT checks output of PV module, compares it to battery voltage then fixes what is the best power that PV module can produce to charge the battery and converts it to the best voltage to get maximum current into battery. It can also supply power to a DC load, which is connected directly to the battery.

3.3.1 I-V Curve:

The Solar Cell I-V Curve in Varying Sunlight is shown in Figure 1. Solar cell I-V curves where a line intersects the knee of the curves where the maximum power point is located.

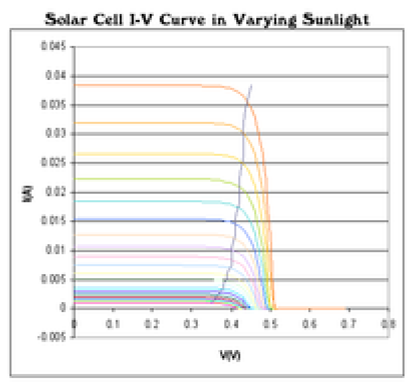

Figure 1 Solar Cell I-V Curve in Varying Sunlight

Photovoltaic cells have a complex relationship between their operating environment and the maximum power they can produce. The fill factor, abbreviated *FF*, is a parameter which characterizes the non-linear electrical behavior of the solar cell. Fill factor is defined as the ratio of the maximum power from the solar cell to the product of Open Circuit Voltage V_{oc} and Short-Circuit Current I_{sc}. In tabulated data it is often used to estimate the maximum power that a cell can provide with an optimal load under given conditions, $P=FF*V_{oc}*I_{sc}$. For most purposes, FF, V_{oc}, and I_{sc} are enough information to give a useful approximate model of the electrical behavior of a photovoltaic cell under typical conditions.

For any given set of operational conditions, cells have a single operating point where the values of the current (*I*) and Voltage (*V*) of the cell result in a maximum power output. These values correspond to a particular load resistance, which is equal to *V* / I as specified by Ohm's Law. The power P is given by $P=V*I$. A photovoltaic cell, for the majority of its useful curve, acts as a constant current source. However, at a photovoltaic cell's MPP region, its curve has an approximately inverse exponential relationship between current and voltage. From basic circuit theory, the power delivered from or to a device is optimized where the derivative (graphically, the slope) *dI/dV* of the I-V curve is equal and opposite the *I/V* ratio (where d*P/dV*=0). This is known as the maximum power point (MPP) and corresponds to the "knee" of the curve.

A load with resistance *R=V/I* equal to the reciprocal of this value draws the maximum power from the device. This is sometimes called the characteristic resistance of the cell. This is a dynamic quantity which changes depending on the level of illumination, as well as other factors such as temperature and the age of the cell. If the resistance is lower or higher than this value, the power drawn will be less than the maximum available, and thus the cell will not be used as efficiently as it could be. Maximum power point trackers utilize different types of control circuit or logic to search for this point and thus to allow the converter circuit to extract the maximum power available from a cell.

3.4 Classification of MPPT:

Controllers usually follow one of three types of strategies to optimize the power output of an array. Maximum power point trackers may implement different algorithms and switch between them based on the operating conditions of the array.

3.4.1 Perturb and observe:

In this method the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common, although this method can result in oscillations of power output. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

3.4.2 Incremental Conductance:

In the incremental conductance method, the controller measures incremental changes in array current and voltage to predict the effect of a voltage change. This method requires more computation in the controller, but can track changing conditions more rapidly than the perturb and observe method (P&O). Like the P&O algorithm, it can produce oscillations in power output. This method utilizes the incremental conductance (*dI/dV*) of the photovoltaic array to compute the sign of the change in power with respect to voltage (*dP/dV*).

The incremental conductance method computes the maximum power point by comparison of the incremental conductance (I_Δ / V_Δ) to the array conductance (I / V). When these two are the same ($I / V = I_\Delta / V_\Delta$), the output voltage is the MPP voltage. The controller maintains this voltage until the irradiation changes and the process is repeated.

3.4.3 Current Sweep Method:

The current sweep method uses a sweep waveform for the PV array current such that the I-V characteristic of the PV array is obtained and updated at fixed time intervals. The maximum power point voltage can then be computed from the characteristic curve at the same intervals.

3.4.4 Constant Voltage:

The term "constant voltage" in MPP tracking is used to describe different techniques by different authors, one in which the output voltage is regulated to a constant value under all conditions and one in which the output voltage is regulated based on a constant ratio to the measured open circuit voltage (V_{OC}). The latter technique is referred to in contrast as the "open voltage" method by some authors. If the output voltage is held constant, there is no attempt to track the maximum power point, so it is not a maximum power point tracking technique in a strict sense, though it does have some advantages in cases when the MPP tracking tends to fail, and thus it is sometimes used to supplement an MPPT method in those cases.

In the "constant voltage" MPPT method (also known as the "open voltage method"), the power delivered to the load is momentarily interrupted and the open-circuit voltage with zero current is measured. The controller then resumes operation with the voltage controlled at a fixed ratio, such as 0.76, of the open-circuit voltage V_{OC}. This is usually a value which has been determined to be the maximum power point, either empirically or based on modeling, for expected operating conditions. The operating point of the PV array is thus kept near the MPP by regulating the array voltage and matching it to the fixed reference voltage $V_{ref}=kV_{OC}$. The value of V_{ref} may be also chosen to give optimal performance relative to other factors as well as the MPP, but the central idea in this technique is that V_{ref} is determined as a ratio to V_{OC}. One of the inherent approximations to the "constant voltage" ratio method is that the ratio of the MPP voltage to V_{OC} is only approximately constant, so it leaves room for further possible optimization.

3.5 Comparison of Methods:

Both perturb and observe, and incremental conductance, are examples of "hill climbing" methods that can find the local maximum of the power curve for the operating condition of the array, and so provide a true maximum power point. The perturb and observe method can produce oscillations of power output around the maximum power point even under steady state illumination.

The incremental conductance method has the advantage over the perturb and observe method that it can determine the maximum power point without oscillating around this value. It can perform maximum power point tracking under rapidly varying irradiation conditions with higher accuracy than the perturb and observe method. However, the incremental conductance method can produce oscillations and can perform erratically under rapidly changing atmospheric conditions. The computational time is increased due to slowing down of the sampling frequency resulting from the higher complexity of the algorithm compared to the P&O method.

In the constant voltage ratio (or "open voltage") method, the current from the photovoltaic array must be set to zero momentarily to measure the open circuit voltage and then afterwards set to a predetermined percentage of the measured voltage, usually around 76%.Energy may be wasted during the time the current is set to zero. The approximation of 76% as the MPP/V_{OC} ratio is not necessarily accurate though. Although simple and low-cost to implement, the interruptions reduce array efficiency and do not ensure finding the actual maximum power point. However, efficiencies of some systems may reach above 95%.

3.6 MPPT Placement:

Traditional solar inverters perform MPPT for an entire array as a whole. In such systems the same current, dictated by the inverter, flows through all panels in the string. Because different panels have different curves and different MPPs (due to manufacturing tolerance, partial shading, etc.) this architecture means some panels will be performing below their MPP, resulting in the loss of energy.

Some companies (see power optimizer) are now placing peak power point converters into individual panels, allowing each to operate at peak efficiency despite uneven shading, soiling or electrical mismatch. Data suggests having one inverter with one MPPT for a project that has east and west-facing modules presents no disadvantages when compared to having two inverters or one inverter with more than one MPPT.

3.6.1 Operation with Batteries:

At night, an off-grid PV power system may use batteries to supply loads. Although the fully charged battery pack voltage may be close to the PV panel's maximum power point voltage, this is unlikely to be true at sunrise when the battery has been partially discharged. Charging may begin at a voltage considerably below the PV panel maximum power point voltage, and an MPPT can resolve this mismatch.

When the batteries in an off-grid system are fully charged and PV production exceeds local loads, an MPPT can no longer operate the panel at its maximum power point as the excess power has no load to absorb it. The MPPT must then shift the PV panel operating point away from the peak power point until production exactly matches demand. (An alternative approach commonly used in spacecraft is to divert surplus PV power into a resistive load, allowing the panel to operate continuously at its peak power point.)

In a grid connected photovoltaic system, all delivered power from solar modules will be sent to the grid. Therefore, the MPPT in a grid connected PV system will always attempt to operate the PV panel at its maximum power point.

MPPT is most effective under these conditions:

- Cold weather, cloudy or hazy days: Normally, PV module works better at cold temperatures and MPPT is utilized to extract maximum power available from them.
- When battery is deeply discharged: MPPT can extract more current and charge the battery if the state of charge in the battery is lowers.

3.6.2 MPPT Solar Charge Controller:

A MPPT solar charge controller is the charge controller embedded with MPPT algorithm to maximize the amount of current going into the battery from PV module. MPPT is DC to DC converter which operates by taking DC input from PV module, changing it to AC and converting it back to a different DC voltage and current to exactly match the PV module to the battery. Boost converter is power converter which DC input voltage is less than DC output voltage. That means PV input voltage is less than the battery voltage in system.

Examples of DC to DC converter are Buck converter is power converter which DC input voltage is greater than DC output voltage. That means PV input voltage is greater than the battery voltage in system. MPPT algorithm can be applied to both of them depending on system design. Normally, for battery system voltage is equal or less than 48 V, buck converter is useful. On the other hand, if battery system voltage is greater than 48 V, boost converter should be chosen. MPPT solar charge controllers are useful for off-grid solar power systems such as stand-alone solar power system, solar home system and solar water pump system, etc.

3.6.3 Main Features of MPPT Solar Charge Controller

- In any applications which PV module is energy source, MPPT solar charge controller is used to correct for detecting the variations in the current-voltage characteristics of solar cell and shown by I-V curve.
- MPPT solar charge controller is necessary for any solar power systems need to extract maximum power from PV module; it forces PV module to operate at voltage close to maximum power point to draw maximum available power.
- MPPT solar charge controller allows users to use PV module with a higher voltage output than operating

voltage of battery system. For example, if PV module has to be placed far away from charge controller and battery, its wire size must be very large to reduce voltage drop. With a MPPT solar charge controller, users can wire PV module for 24 or 48 V (depending on charge controller and PV modules) and bring power into 12 or 24 V battery system. This means it reduces the wire size needed while retaining full output of PV module.

- MPPT solar charge controller reduces complexity of system while output of system is high efficiency. Additionally, it can be applied to use with more energy sources. Since PV output power is used to control DC-DC converter directly.

MPPT solar charge controller can be applied to other renewable energy sources such as small water turbines, wind-power turbines, etc.

4. RESULTS AND DISCUSSIONS

One simple solar panel that has standard value of insolation and temperature has been included in the simulation circuit. From all the cases, the best controller for MPPT is incremental conductance controller. This controller gives a better output value for buck, boost converter. Hence this controller will give different kind of curves for the entire converter. In simulation Buck converter show the best performance the controller work at the best condition using buck controller. The Circuit diagram for Proteus Simulation is shown in Figure 2.

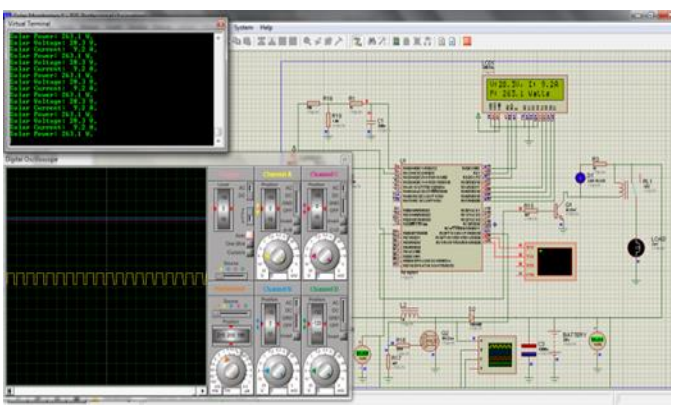

Figure 2 Circuit diagram for Proteus Simulation

5. CONCLUSION

The simulation results of the solar powered cellular base station suggests that it is more cost efficient to deploy grid connected system than to deploy standalone system in Grid connected systems are suitable if the supply of solar energy is reliable. In other words it is suggested to use grid connected system in areas with adequate power supply. If the supply of electrical energy from the grid is not reliable then it is suggested to use standalone system though it is more costly.

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