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MICRO INVERTER WITH MPPT: CONCEPT AND DESIGN IN PHOTO VOLTAIC RESIDENTIAL SYSTEM AIMING TOWARDS LOCALIZED MICRO GRID INTRODUCTION IN BANGLADESH

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Abstract- *Micro inverter in PV electrical systems is a prominent solution for individual users as for getting greater reliability, efficiency, productivity and prolonged lifetime. Instead of a matched string of solar panels, micro inverter can deliver ac voltages to a common ac bus for micro grid systems and also, maintenance is much safer here. In this paper, we have put the efforts to clarify the concepts for introducing it in condition of Bangladesh. Furthermore, MPPT algorithm related to micro inverter's use in system is justified and a newer approach is proposed to increase the feasibility in use in micro-grid operation.*

Keywords: PV solar systems, micro-inverter, MPPT, micro-grid.

1. INTRODUCTION

The need to use renewable energy for satisfying our residential consumption of power is a burning question now. Day by day, the total electrical system gets worse to worsen for fulfilling the incremental demands of industries, household users, irrigation machineries and nevertheless the backup sources of UPS, IPS, battery vehicles etc. The no of power plants have been increased in the last few years but, the total cost and fuel management is under question for choosing the best futuristic steps taken in this poor country. Whereas, Bangladesh herself, is a country of having great sunlight! We can use this as our source of electricity for our residential users. Now, where a localized grid can be developed in some economically advanced area for saving that amount of energy, then those can be provided to other region instead of making load shed there. The concept is well judged and approved and we are going to give a better insight to these in the preceding sections, where, micro-inverter with MPPT algorithm is elaborately described and a new one is designed for adopting in the natural situation of Bangladesh to form a micro grid.

2. MICRO INVERTER IN PV SOLAR SYSTEM

For photovoltaic system, solar cell to produce DC current to charge a battery or directly coupled to AC grid via an inverter, is our concern in this paper. Solar cell can produce the direct current when a load is applied in between its output. Generally, there is an inverter at the output of the solar panel (PV unit) to produce ac voltage at its output, to drive the 98% demand of a house. This inverter can be of two types[3], [4]. Which are :

1. String type: Single inverter for a series of PV panels or cells.
2. Micro inverter type: Dedicated for each PV panel.

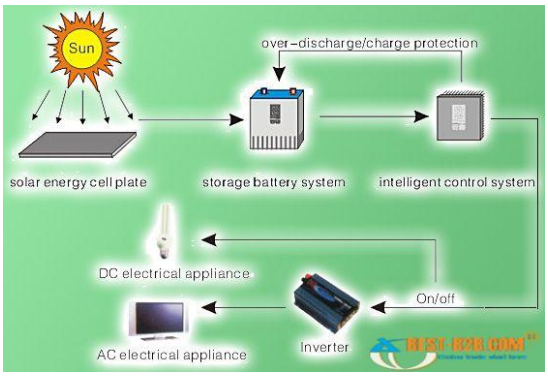

Fig 1: A typical orientation of household solar energy

Micro inverter [3] is a newly accepted hardware to be a far better replacement of string type. It is a dedicated inverter module for each and every solar panel to produce individual maximum power possible. Despite of its cost and no of needed module, in contrast of String inverter, micro inverter has the following advantages [6]:

a. *Power Production*: Micro-inverter can have 5-25% more power production from solar panels as they can manage to maximize the power production from each solar panel (utilizing MPPT). The string inverter will produce power at the rate of the least efficient solar panel in the string. This is caused by minor variations from panel to panel. Those variations can make as much

as 5% difference between the most and least efficient panels in the string. That micro inverter produces the maximum total power available from that panel, regardless of its age or condition. So, all panels in the array are producing power at their maximum output. Even an accumulation of dirt or leaves, even shading, on a single panel will adversely affect the power production of the entire string with a string inverter. The differences actually increase with the age of the system.

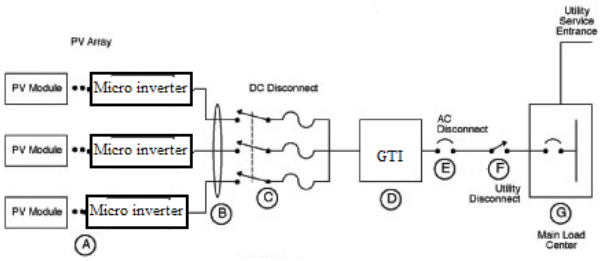

Fig 2: PV module with Micro inverter in on/off grid operation in residential house.

b. *Command and Control*: The string inverter monitors and measures only the total power produced by the string. In the micro inverter approach, each panel is monitored and controlled separately. One can look at the micro system and immediately identify and particular panel or inverter that is not operating properly.

c. *Reliability*: Electrical engineers always try to design any system so that a single failure will not bring whole system down. The string inverter architecture is inherently vulnerable to system failure in the event of a single fault. The string inverter monitors only the sum of the power produced. The micro inverter has a minor reduction in system output instead of a system collapse for any one's fault as they appeared in parallel position.

d. *Longer Life*: The Mean Life of micro inverters is much more than the life of the Solar Panels compared to the 5-10 year life of String Inverters because of low operating temperature to handle and at low voltages of individual solar cell. Also, to handle the lower power, no large electrolytic capacitor is needed. This can eliminated extra maintenance cost.

e. *System Scalability*: The string inverter approach does not easily lend itself to add extra PV array. If the string is already operating at full potential, it must be replaced with a larger or a second string inverter. The micro inverter approach is perfectly suited to scaling. One can easily add as little as 200 watts or as much as 10 KVA to the existing system with relative ease and simplicity.

3. MPPT IN PV SYSTEM

MPPT [1], [2] is for Max Power Point Tracking for the case of solar cell to draw maximum power possible from them, for the specified environmental and structural condition. MPPT is automatic electronic control to adjust the electrical load. This are the algorithms developed and applied in designing and driving the on grid /off grid specialized converters / inverters, which are to use in between solar cell and load center. Main causes to search for MPP are ambient temperature and irradiance related. As temperature rises, the output power decreases up to 22% for 50 degree which is seen in fig 3.

The causes behind this temperature effect are:

- Increased temperature makes the outer band electrons to gain more energy. So that, the effective band gap becomes smaller then.
- Most of the parameters are affected by lower band gap energy to produce less output voltage and power. Mostly, the open circuit voltage.

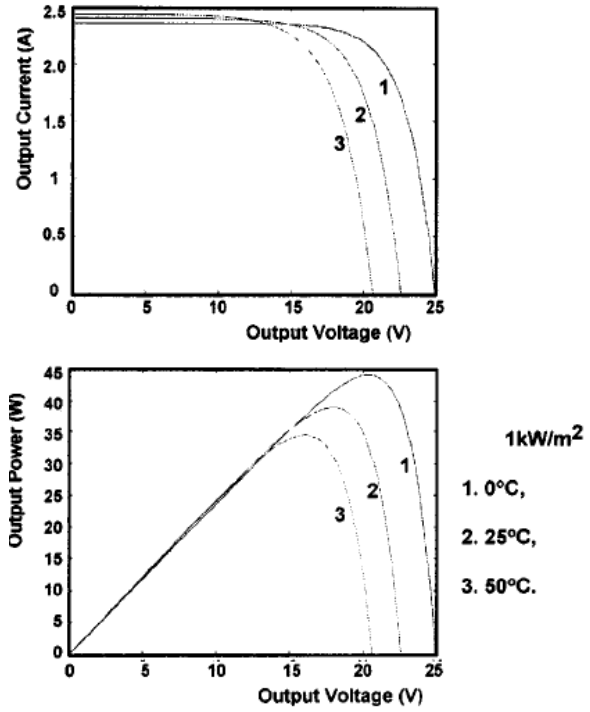

Fig 3: Characteristic curves of the PV modules output V, I and P in various temperature condition

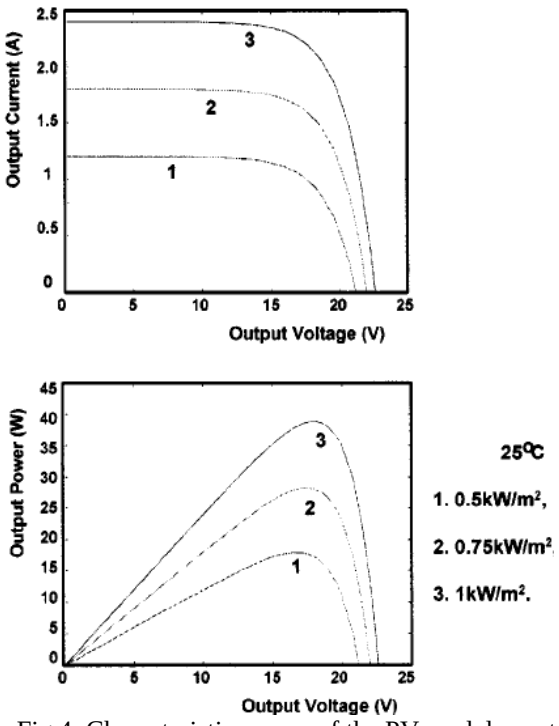

Fig 4: Characteristic curves of the PV modules output V, I and P in various insolation condition

The amount of solar irradiation is dependent upon geographical position, rain condition over years and other issues. But, still a MPPT can be useful to increase the power drawn during these condition, to 5% more if effectively employed.[1], [2],[10],[9].

Now every PV panel has its own I-V pattern because of:

1. Manufacturing tolerance
2. Shading difference
3. Dust deposited
4. Angular displacement in mounted position.
5. Miscellaneous

For a specific panel with a fixed environmental condition, the maximum power can be corresponds to the knee point in I-V curve.

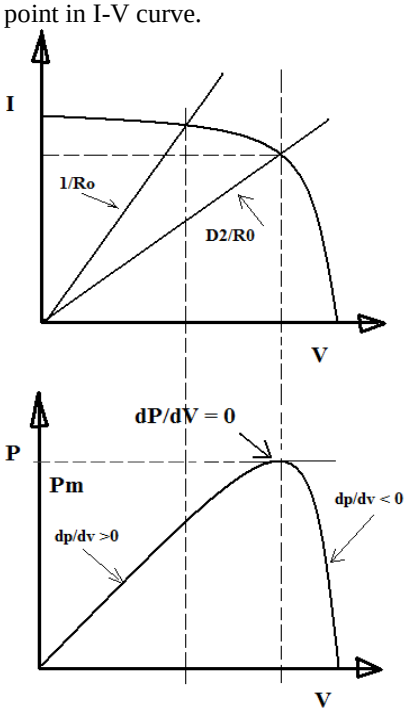

Fig 5: Working principal of any MPPT algorithm

So, for the definite pattern, an algorithm will search for that Vm, to vary a converter / inverter's, duty / input resistance to get that Vm at the output. The resultant Pm is drawn to the load.

Let the controller is taking P and V as in samples.

Then, difference is measured by it as:

dp= {p(k+1) – p(k)}

dv= {v(k+1) – v(k)}

so, dp/dv is compared to be > or = or < zero.

Satisfying, dp/dv =0, the MPPT controller will drive an output to vary the input resistance to the PV panel, for maximum power to draw.

Now this controller can be a DC/DC converter of either buck or boost, situated in between the PV panel and load for what, duty can be varied as to get to the MPP.

Considering, a buck converter,

$V_{out} = D * V_{in}$

For impedance transferring, it becomes:

$R_{out} = D^2 * R_{in}$

So, $R_{in} = R_{out} / D^2$

Here, output resistance is fixed and duty of the converter is accordingly varied to reach the Ri which corresponds to the maximum power point for that PV panel. In this way, a MPPT works. Now, to do it in automatic mode, several techniques are employed. Like as:

1. Perturb & observe (P O)
2. Incremental conductance (IC)
3. Parasitic capacitance (PC)
4. Voltage based peak point tracking (VPPT)
5. Current based peak point tracking (IPPT)

Based on the facts that, for unidirectional error, no 1 is suitable to reach nearer the peak point quickly and for a quickly varying peak point, incremental conductance is suitable to avoid fluctuation and stay at the peak point so, we are going to propose the following MPPT algorithm.

4. OUR PROPOSED MPPT ALGORITHM

In the previous section, perturb and observation method of peak tracking is stated. Now, in our algorithm this method should be followed as long as the error in output power signal is greater than a pre-defined error check value. But, when it goes down under this value, we are switching towards incremental conductance method, as this means, the operating point is near the peak point. Near the peak point, the IC method is useful to avoid fluctuation around MPP and hold on the desired point.

Here, conductance is defined the ease of PV panel, to produce rated current from rated voltage.

In this method:

Let, V= Module output voltage

I = module output current

So, module output power, $P = V * I$

Now, by differentiating it with respect to V yields:

$dP/dV = V * dI/dV + I$

For peak point on P-V curve, $dP/dV = 0$.

So, Incremental conductance can be found as:

$dI/dV = -I/V$

To the left of MPP:

$dI/dV > |-I/V|$; To the right of MPP: $dI/dV < |-I/V|$

So the two methods are combined in the following figure for developing the MPPT algorithm.

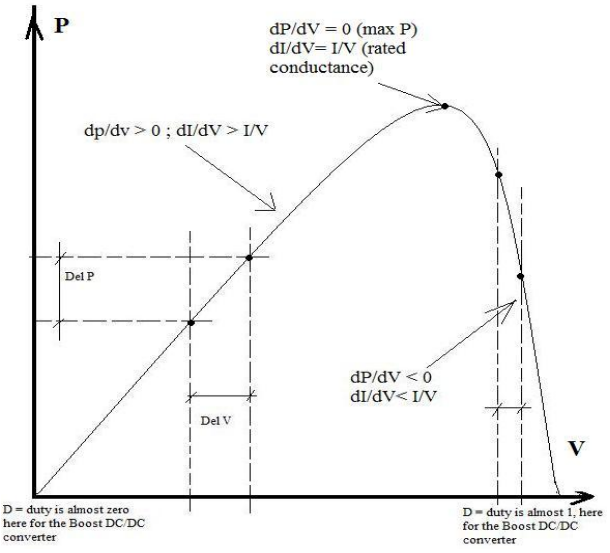

Fig 6: PV graph for developing a MPPT algorithm

The proposed algorithm flow chart is as follows:

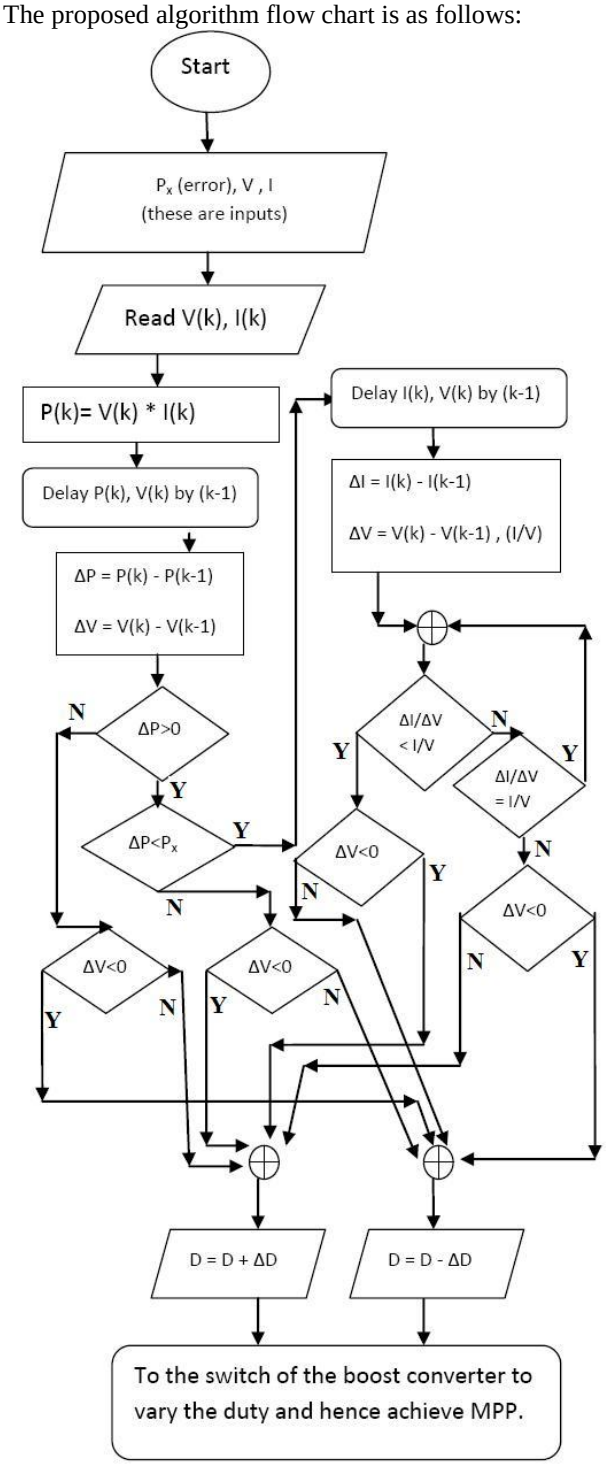

Fig 6: Proposed MPPT algorithm flow chart

5. MICRO GRID

The concept of localized micro grid [6], [10] means a collection of consumers, generators and potential energy storage entities which are connected together. It is the main grid connected network, but may act as an islanded grid in case of main utility failure. The source of power are local power generators or most effectively, for the green environment, the renewable energy sources. For the condition of Bangladesh, Micro grid introduction can be useful for the below mentioned causes (but not limited to):

1. The national grid has a huge shortage in power supply. So, local sources can be used to reduce the peak time demand on it for a region.
2. The natural calamity occurs frequently in most of the parts of Bangladesh and power failure for prolonged days to weeks is common in the rural or densely populated areas. During that time, for power to supply to the victims, the renewable sources in micro grid structure can be a valuable solution.
3. Large scale of renewable sources from each and every household user can form this grid. So, at the peak demand, by exporting power to the neighbors at the specified smaller voltage level, one can make profit out of this system.

The technical issues with a micro-grid or more likely named by 'reliable facility micro-grid' are: [7], [8]

1) Interconnectivity: This describes the complexity generated from interconnection in between micro and macro grid. The sources of this complexity are:
   - A. power generation source types (their dynamics and transients)
   - B. No of points of grid tie (locations as to regulate voltage and frequency).
   - C. Penetration level of micro-grid inside the macro grid for backup purpose to the load centers. Hence the allowable immediate transients after bulk utility failure on micro grid sources are to be justified.
2) Intentional islanding: This is the seamless transition of the macro to micro grid in cases of macro-grid failure. Anti-islanding or facility micro-grid mode of operation can also be adopted and as needed, the control schemes are designed so.[7], [8]
3) Controlling the system: So, control scheme is developed aiming towards the islanded operation of micro grid in case of main grid failure or fault, high pricing rate of mains, ensuring power quality to certain critical loads and to increase reliability to a great extent.

Now to combine all these we can see that, a micro-grid formation using the solar panel based autonomous system can use individual micro inverters to attain dynamically controllable MPPT for ensuring highest production possible and enhancing power quality, reliability, continuity and then, the renewable source of solar (or even wind, thermal, biodiesel, bio mass etc) thus, be a active blessing for us. The cost which was the main drawback for using micro inverter is not a big issue as, the no of units used in this small grid is not big. But all the benefits of micro inverter are there to serve us.

Also, Grid Tied Inverter (GTI) [1], [9], [10] or commonly known as synch inverter can play an important role in detecting the requested island operation of the micro grid by the following methods:

i) Under / over voltage transient detection
ii) Under / over frequency of main grid
iii) Voltage phase jump detection
iv) Harmonic detection
v) By slip mode frequency shift method
vi) Impedance measurement seen by the center

The scenario consists of various electrical components and instruments for the operational PV based micro grid linked with main utility is given below:

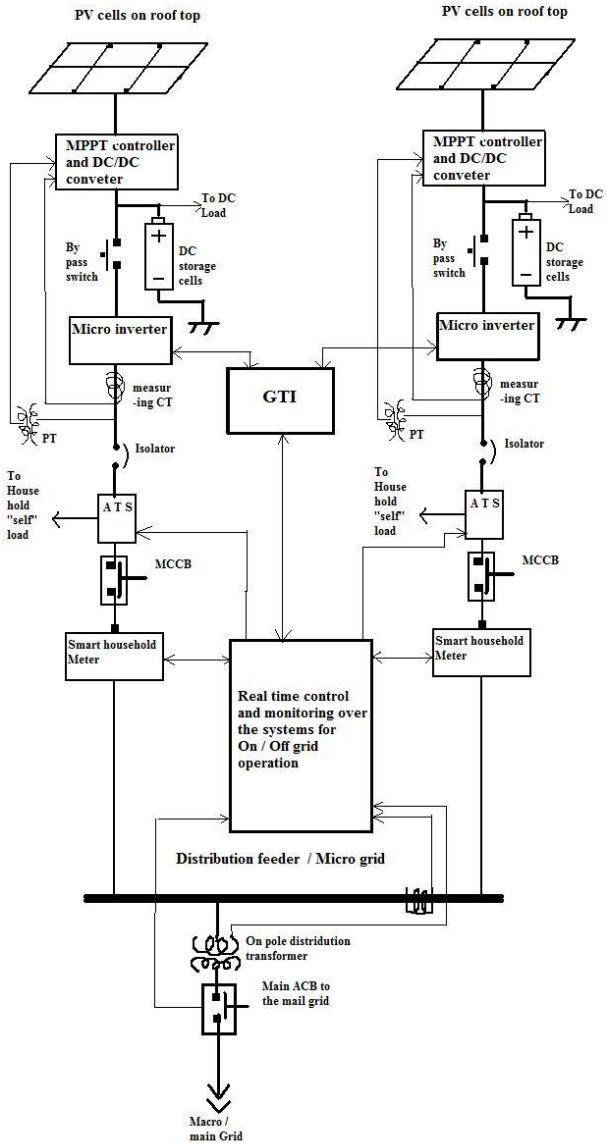

Fig 7: One line structure of the operational electrical system

6. CONCLUSION AND FUTURE PLAN

So that, so far we have presented and clarified the various issues of micro grid structure with PV systems as in sources. We have demonstrated the maximum power point tracking methods and developed a flowchart, on the basis of which a sustainable algorithm and simulation process can be generated. The micro inverter is presented as the most prominent hardware for these purposes in near future. Now, in our future plan of research works, we are to design such types of micro inverters aiming at incorporating MPPT algorithm and reducing the cost. Moreover we are towards the control scheme to design for sustainable operation and control in micro grid backbone for our country. Then in turns, smart grid systems to reduce existing system loss, load shedding patterns etc should be aimed at, with care and perfection in our future course of plan.

7. REFERENCES

[1] Vikrant. A. Chaudhari, "Automatic Peak Power Tracked for Solar PV modules using dSPACE® software", july 2005.

[2] Xuejun Liu and A. C. Lopes, "An improved perturbation and observe maximum Power Point Tracking Algorithm for PV arrays", IEEE PESC, 2004, pp 2005 – 2010.

[3] http://en.wikipedia.org/wiki/Solar_micro-inverter#Description (10/07/2011)

[4] http://www.renewableenergyworld.com/rea/news/podcast/2010/02/micro-inverters-vs-central-inverters-is-there-a-clear-winner (10/07/2011)

[5] http://greenworldinvestor.com/topics/renewable-energy/. (11/7/2011)

[6] Z. Ye. R. Walling, N. Miller, P.Du, K. Nelson, "Facility Microgrid"

[7] Ye, Z.; Walling, R.; Garces, L.; Zhou, R.; Li, L.; Wang;T. "Study and development of Anti islanding control for Grid – connected Inverters". NREL/SR – 560-36343. Golden Co; National Renewable Energy Laboratory, May 2004.

[8] Tom Loix, Kuleuven, "Micro grids: different structures for various application"Leonardo Energy, Feb 2009.

[9] www.ieee.org

[10] http://en.wikipedia.org/wiki/Main_Page

8. NOMENCLATURE

Symbol	Meaning	Unit
V	Module output voltage	(v)
P	Power	(Watt)
Px	Error in power value	(Watt)
I	Module output current	(A)
Rin	Input resistance to the source	(ohm)
Rout	Output resistance to the source	(ohm)
D	Duty of converter	n/a