

Issues regarding the usage of MPPT techniques in micro grid systems

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Abstract. The main objective of the control strategies applied at hybrid micro grid systems (wind/hydro/solar), that function based on maximum power point tracking (MPPT) techniques is to improve the conversion system's efficiency and to preserve the quality of the generated electrical energy (voltage and power factor). One of the main goals of maximum power point tracking strategy is to achieve the harvesting of the maximal possible energy within a certain time period. In order to implement the control strategies for micro grid, there are typically required specific transducers (sensor for wind speed, optical rotational transducers, etc.). In the technical literature, several variants of the MPPT techniques are presented and particularized at some applications (wind energy conversion systems, solar systems, hydro plants, micro grid hybrid systems). The maximum power point tracking implementations are mainly based on two-level architecture. The lower level controls the main variable and the superior level represents the MPPT control structure. The paper presents micro grid structures developed at Politehnica University Timisoara (PUT) within the frame of a research grant. The paper is focused on the application of MPPT strategies on hybrid micro grid systems. There are presented several structures and control strategies and are highlighted their advantages and disadvantages, together with practical implementation guidelines.

1. Introduction

The paper presents some issues regarding the usage of maximum power point tracking (MPPT) approaches within microgrid systems. The authors studied several types of microgrid structures. Some of them implemented on laboratory rigs at University Politehnica from Timisoara, other structures were only studied in dedicated modelling and simulation software such as Matlab-Simulink [1].

The usage of renewable energy resources has significantly increased in the past years at global level. It becomes obviously a domain of very high importance. The scientific community presents a great interest for the domain of renewable resources especially for wind and solar energy. The solar and wind energy have the advantage of being clean and free. However, one of the main drawback of the wind resources is that it has a sporadic character. Therefore, in a microgrid there are grouped several energy resources and supplementary there are included also energy storage systems (supercapacitors, batteries, other additional equipment) [2-5].

In the case of wind energy conversion system there is harvested the energy and converted into electrical energy. The output power of course depends on wind speed. The problem occurs due to the non-linear characteristic of the wind aggregate. There are developed several techniques that aim to extract the maximum amount of energy at any wind speed.



Similarly, the solar energy is a renewable energy resource which is converted into electrical energy by using photovoltaic (PV) cells. There are two main parameters - radiation and temperature – that disturb the output of the photovoltaic panels. In the case that irradiance increases then current increases and the variation of the voltage is smaller. In the case that temperature increases, open circuit voltage decreases, while if intensity of solar radiation increases, short circuit current increases. Therefore, the I-U and respectively the P-U characteristics change with temperature and irradiance variation, fact that leads to a shift of the maximum power point (MPP) on the characteristic. So, the most accurate MPPT techniques take into account these parameters [6-10].

Nowadays, in the technical literature there are used several MPPT technique types for solar and wind energy system. In the case of MPPT approaches for wind energy conversion systems there are widely spread three methods: perturb and observe (P&O); tip speed ratio (TSR) and respectively optimum-relation-based (ORB). In the case of MPPT strategies for solar energy conversion system there are mentioned: constant-voltage tracing; perturb and observe (P&O) and incremental conductance. Of course, this are only the most used techniques. In literature, there are many other related and variations of MPPT strategies presented and studied. Each of them presents advantages and disadvantages. The system engineers must perform studies on a certain microgrid implementation and choose the most suitable control strategy [11-13].

2. Issues on MPPT techniques applied at microgrid systems at PUT

The paper presents the proposed microgrid topology – at an experimental setup at Politehnica University Timisoara (PUT) laboratory [1].

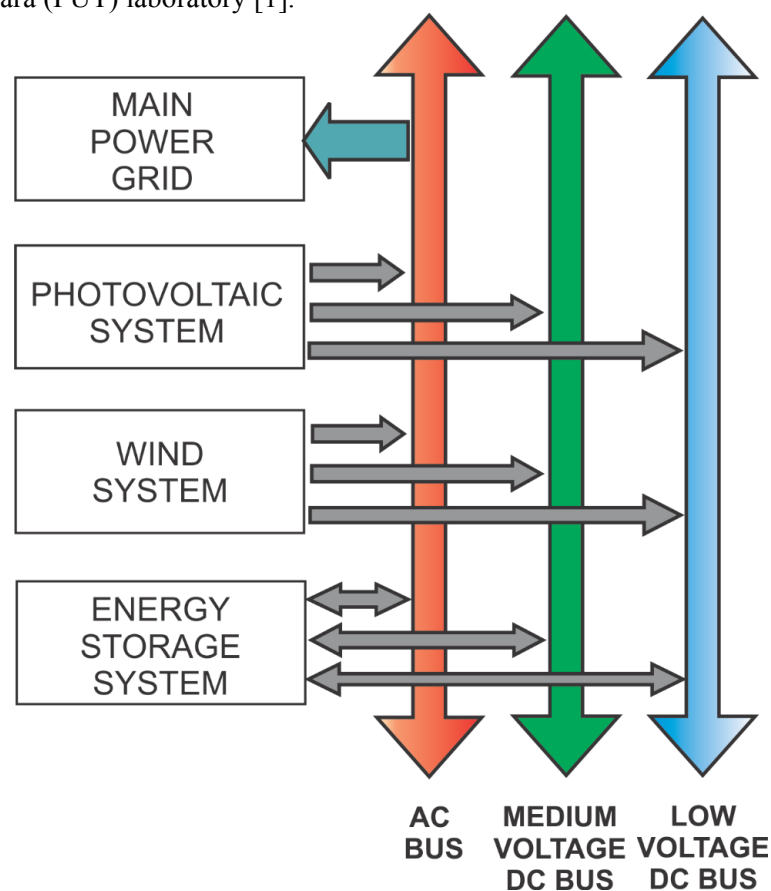


Figure 1. Proposed microgrid topology – experimental rig at UPT laboratory

In Figure 1, there is detailed the considered structure of the experimental microgrid. The main components are: photovoltaic subsystem; wind subsystem; energy storage (capacitor bank) and the interface with the power grid system. The system is based on three power buses: one for *ac* voltage and two for *dc* voltage (low and medium voltages). There were conducted several experiments and also different simulations of the microgrid components. In the case of wind energy subsystem, the experimental rig includes: asynchronous machine (squirrel cage), permanent magnet synchronous machine and a modified induction machine - doubly fed with α lagged windings [14].

In the case of the wind system there must be done some considerations regarding the mathematical modelling. The wind aggregate converts rotational mechanical energy into electrical energy. As already was stated the amount of electrical energy heavily depends on the availability of the wind. The variations of wind speed, lead to the increase or to the decrease of the electric energy production. Therefore, in the case of wind energy conversion systems the site selection is very important.

The mechanical power that is generated by the wind aggregate is given by relation (1):

$$P = 1/2 * C_p(\lambda, \beta) * \rho * A * V^3 \quad (1)$$

where: P – power; A – rotor swept area; ρ - air density; C_p - power coefficient; λ - tip speed ratio; β - blade pitch angle; V - wind speed.

Another issue is that the maximum value of C_p can be 0.48. There results that it cannot be converted all wind energy into electrical energy. In the technical literature is mentioned the Betz limit. There can be converted the wind energy only up to 48%.

For the wind energy conversion system, there must be known the specific wind turbine power characteristic (curve). The maximum power characteristics must be via off-line experiments in wind tunnels or via simulations on individual power turbines. Having this knowledge there can be customised the different MPPT approaches and strategies.

In the case of the solar energy conversion systems there are several mathematical models that model the photovoltaic cell. In the technical literature, the most used are: linear power model and the classical single diode model [15].

In this case, the MPPT is a technique that uses power inverters, solar battery chargers and related devices in order to obtain the maximum possible power from one or several photovoltaic cells/panels. The power output of a photovoltaic cell has a quite complex relationship that includes parameters such as: solar irradiation, temperature and total resistance. It is non-linear and can be studied based on the I - U (current-voltage) characteristic. The main goal of an MPPT system is to measure the output of the photovoltaic cells and to deliver the suitable resistance (load) in order to obtain the maximum possible power under any particular environmental conditions. MPPT equipment is usually embedded into an electric power converter that provides the required voltage or/and current conversion.

Figure 2 presents the conceptual diagram for generic MPPT methods. This structure is applicable both at solar and wind systems. There can be noticed that the MPPT approach is based on two hierarchic levels: superior and inferior. At the superior level, there are considered the human operator experience and some input from sensors and other measurement devices. The output at this level represents practically prescribed data for lower control system. The lower level (base level) practically implements the dedicated control system (there are PI controllers, fuzzy, etc). Its outputs represent actually the command variables (current, voltages, etc).

In Figure 3, is represented the MPPT strategy applied at a wind energy conversion system equipped with a modified induction machine – doubly fed induction generator. The generator has separated windings for excitation and load. The considered generator is presented in the research papers of the member of the research grants [14]. The structure has the wind turbine coupled via a gear box with the electrical machine. The output of the electrical machine is three-phased. The input in the MPPT controller is represented by the rotation speed, and the computed output is the prescribed optimal power (from the power characteristic – the maximum power point). The low-level controller acts on the electronic power converter achieving its required operating point.

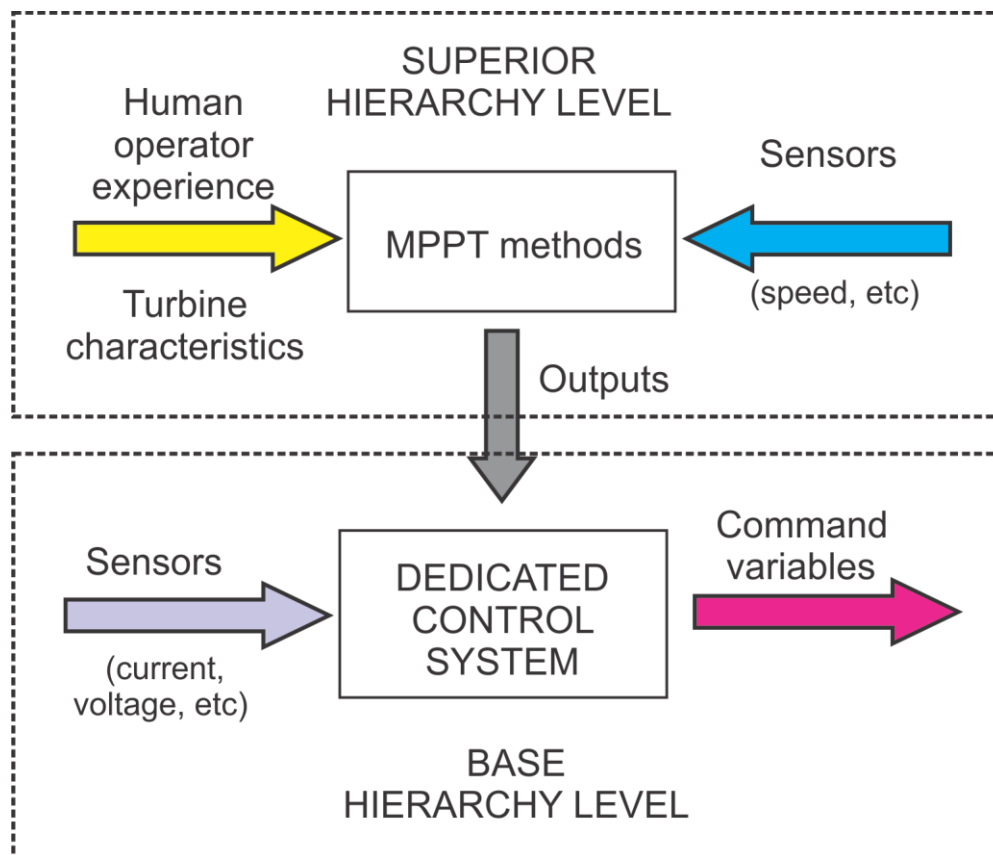


Figure 2. MPPT methods – conceptual diagram

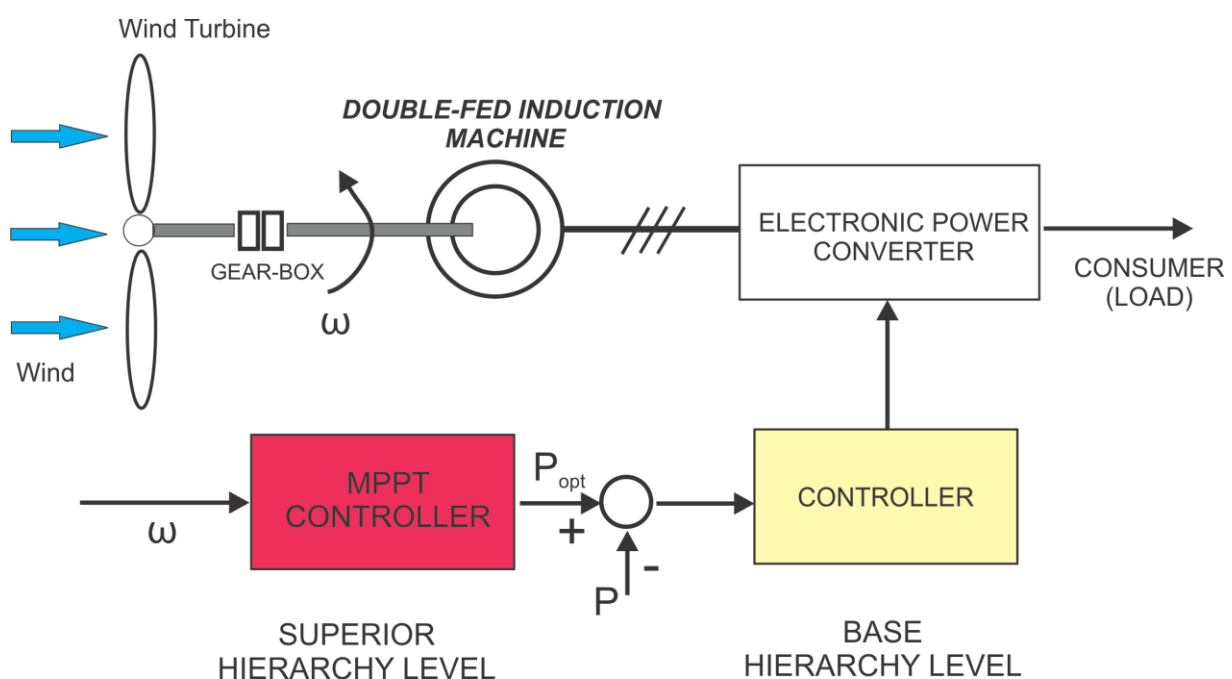


Figure 3. MPPT method applied at a wind energy conversion system

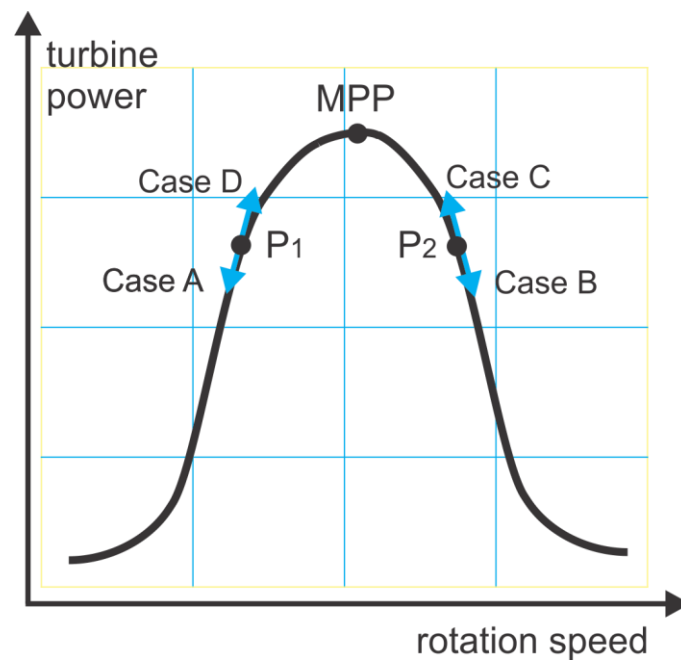


Figure 4. MPP – wind turbine characteristic

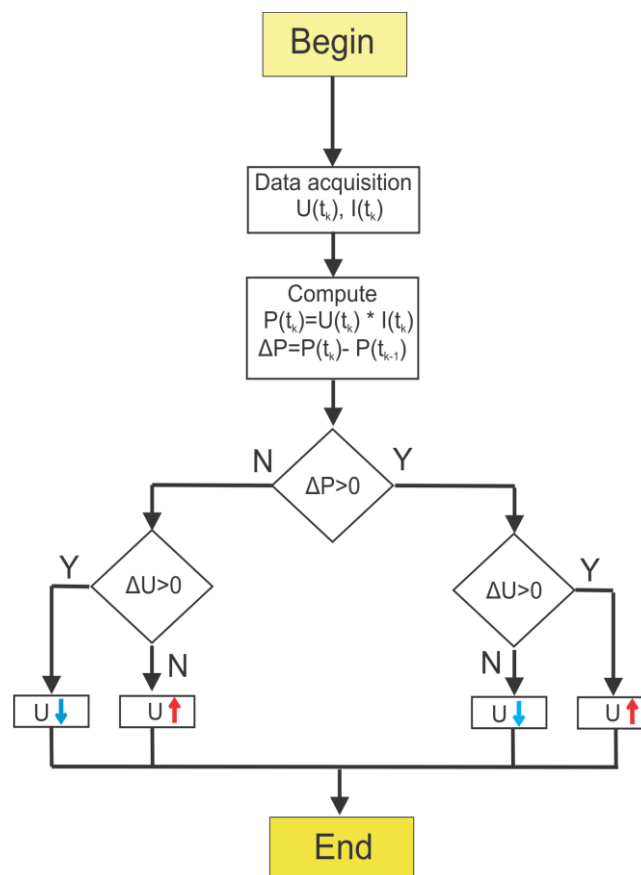


Figure 5. MPPT – Perturb and Observe algorithm diagram

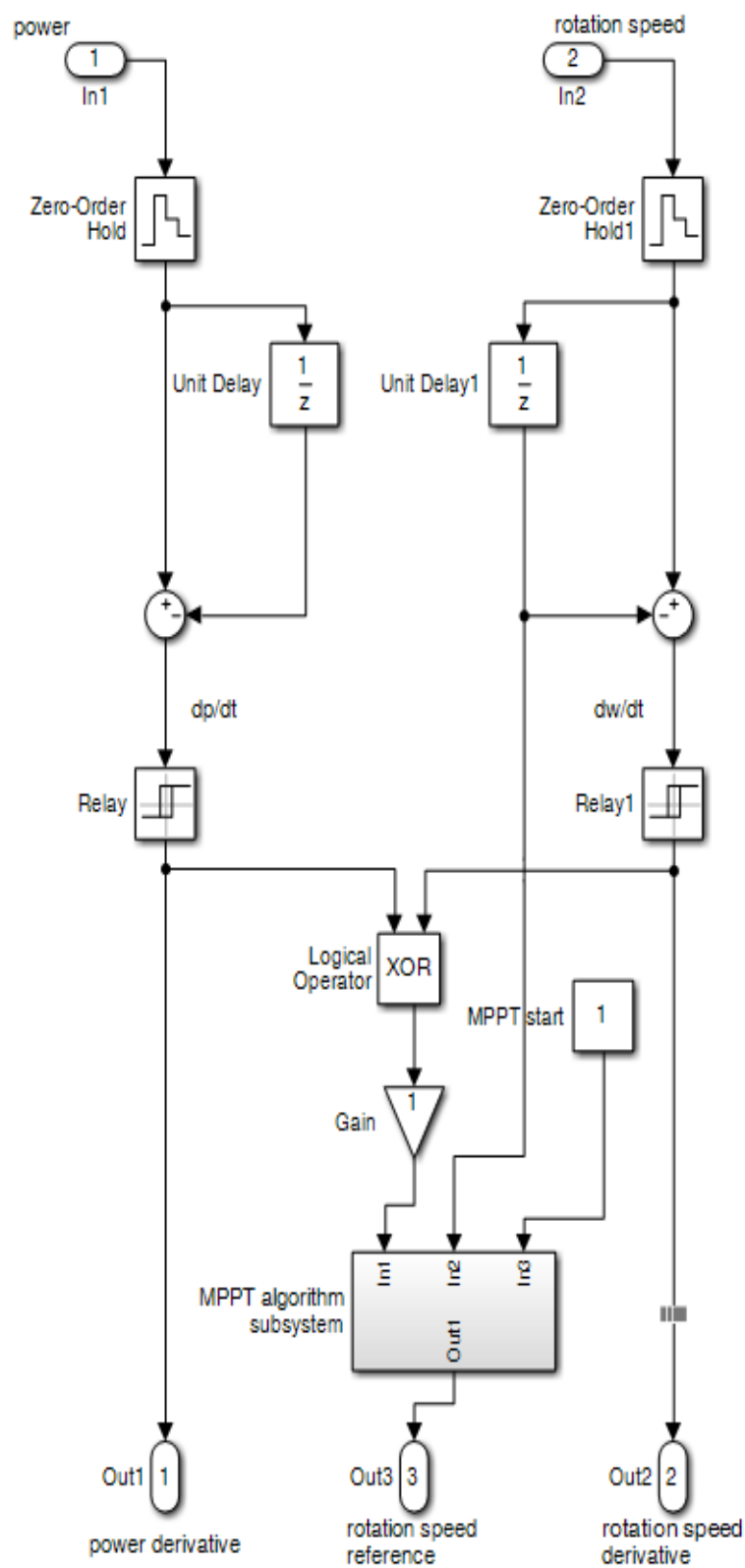


Figure 6. MPPT strategy – Simulink block diagram

In Figure 4, there is presented a typical wind turbine characteristic (turbine power vs rotation speed) with exemplification of the searching/tracking of the MPP (maximum power point). There are the four cases (A, B, C and D) regarding the two operating points below the MPP (P_1 and P_2). Practically, the operating points are shifted towards the MPP. The MPP tracking is further detailed in the Figure 5, with the notice that the figure 5 is elaborated for the case of a solar system. The same logic can be also applied in the case of wind energy conversion systems.

In Figure 5 there is presented the block diagram of the MPPT algorithm – Perturb and Observe in the case of a solar energy conversion system. In technical literature, there are presented different variants of this algorithm that consider the influence of irradiation and temperature. Maximum power point trackers use several types of logic to search for this point (the MPP) and consequently to allow the power converter to extract the maximum power available from a photovoltaic cell/array. The Perturb and Observe algorithm practically computes the power $P(t_k)$ by using the data acquired (voltage (U_{t_k}) and current (I_{t_k})) and then it compares with the previous computed power $P(t_{k-1})$. The algorithm permanently perturbs (is continuously reiterated) the system; if the functioning point on the characteristic has positive variation and consequently the direction of the perturbation is reversed if it has negative variation. So, there is achieved in time the maximum power point on the characteristic of the energy conversion system. This approach is of the “hill climbing” type. Practically it depends on the characteristic curve of power versus voltage near the maximum power point.

The main issue of this approach is that there occur serious oscillations around the maximum power point. So, there must be considered a trade-off between a rapid tracking versus oscillations, and also there is the issue of user predefined constants. There are guidelines for choosing the time step and the method practically try to harvest a maximum possible amount of energy within a preset time period. As already stated, this algorithm can be used both in the case solar and wind energy conversion systems and is widely spread in microgrids implementations.

In figure 6, there is presented the MPPT strategy implementation – in dedicated simulation environment (Matlab-Simulink). The simulation studies performed by the authors used also this structure implemented in Simulink. There were considered different structures for the modular micro grid implementations [16-19].

3. Conclusions

In the technical literature, several variants of the MPPT techniques are presented and particularized at certain applications (wind energy conversion systems, solar systems, hydro plants, micro grid hybrid systems). The maximum power point tracking implementations are mainly based on two-level architecture. The first level controls the primary variables and a second one represents the MPPT control structure.

Paper presents micro grid structures developed at Politehnica University Timisoara. Also, the topic is focused on the application of MPPT strategies on hybrid micro grid systems. There are proposed structures and control strategies and are highlighted their advantages and disadvantages, together with practical implementation guidelines.

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