

PV Output Power Fluctuations Smoothing and Optimum Capacity of Energy Storage System for PV Power Generator

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Key words

Capital cost, Energy Storage System, Maximum Power Point Tracking, Optimal capacity, PV output power smoothing.

1. Interest of the Work

In recent times, Global warming is a burning issue as the CO_2 density increased highly in the atmosphere. Therefore, clean and renewable energy sources must be introduced to reduce the CO_2 density. Among various renewable energy systems, PV systems are expected to play a promising role as a clean power electricity source in meeting future electricity demands. However, the power output of PV systems fluctuates depending on weather conditions, season, and geographic location. In the future, when a significant number of PV systems will be connected to the grids of power utilities, power output fluctuation may cause problems like voltage fluctuation and large frequency deviation in electric power system operation [1]. Therefore, for the penetration of large PV system's output power in the utility without reduction of the reliability of utility power systems, suitable measures must be applied to the PV systems side. On the PV system side, storage devices like batteries can be used as smoothing devices for a PV system's output. There have been investigations aimed at improving the performance of PV systems equipped with batteries [2]. However, energy storage device increases capital cost, as it needs maintenance. The maintenance cost mainly depends on charge/discharge action of battery. In those investigations, the optimal size of battery and battery parameters for charge/discharge action is not considered.

2. Objective

To design a methodology for PV generator, which will maintain storage energy ratio of the battery up to 50% and will select optimal size of the battery needed for smoothing PV output power fluctuations.

3. Methodology

In this paper, PV output power fluctuations are levelled using the proposed methodology through battery charge/discharge action and the optimal size of the

battery is calculated to minimize the capital cost. In the optimization problem of Energy Storage System (ESS), the control parameter for ESS is selected in all combinations and local search is performed to find the optimal size of the battery. The proposed method is compared with conventional MPPT. From the simulation results, it has been found that the proposed method is able to achieve the required control parameters for ESS and the optimal battery and inverter capacities to minimize the total cost and to minimize the frequency deviations. The small power system model [4] used in this paper is shown in Fig. 1.

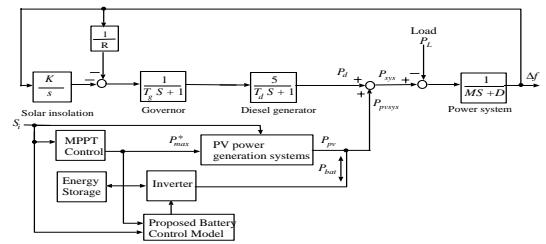


Fig. 1. Small power system model

The battery charge control model is shown in Fig. 2.

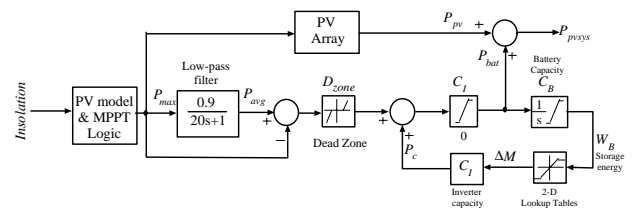


Fig. 2. Battery charge control model

The value of output power fluctuations below dead zone value will be present in the system. This model adds correction power P_c to D_{zone} output. P_{bat} is computed through the limiter ranged from C_i to zero. If P_{bat} becomes positive/negative, battery has discharge/charge action. W_{bat} is calculated by integrating P_{bat} . To maintain storage energy ratio $\xi (=W_{bat}/C_{bat})$ to near 50%, the lock up table used is shown in Fig. 3

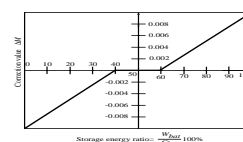


Fig. 3. Lockup table for correction value ΔM

The algorithm used for optimization is shown in Fig. 4

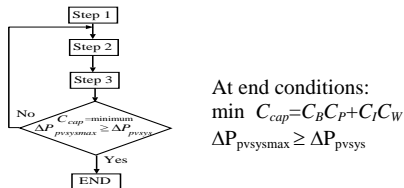


Fig. 4. Algorithm of the optimization

Step 1: Maximum output power fluctuation tolerance limit $\Delta P_{pvsysmax}$ is set.

Step 2: In this steps control parameters of ESS (M , D_{zone}) are set.

Step 3: The charge/discharge is performed. ΔP_{pvsys} is calculated. It searches C_B and C_I to minimize the capital cost using the local search which is shown in Fig. 5.

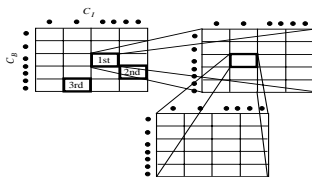


Fig. 5. Local search on step 3

Step 4: The result of step 3 is evaluated. If it satisfies at end conditions, process terminated else it goes to step 2.

The simulation parameters for small power system are: Inertia constant, $M=0.150$ puMW.s/Hz, Damping constant, $D=0.008$ puMW/Hz, Governor Time constant, $T_g=0.10$ s, Diesel Generator Time constant, $T_d=8$ s, Speed regulation, $R=2.5$ Hz/puMW. Parameters for PV array are: Rated output power=241 kW, $V_{oc}=588.80$ V, $I_{sc}=520.37$ A, $N_s=16$, $N_p=65$, Total no. of cells=62,400.

4. Simulation Results

TABLE I shows the simulation results for the optimization algorithm.

TABLE I. Optimization results

Sl.	Case 1	Case 2	Case 3	Case 4
ΔM	0.002	0.001	0.002	0.007
D_{zone}	0	0	0	0
ΔP_{pvsys}	± 34 kW	± 12 kW	± 11 kW	± 15 kW
C_B	60 kWh	160 kWh	180 kWh	200 kWh
C_I	130 kW	200 kW	170 kW	230 kW
Cost	237 k \$	249 k \$	381 k \$	485 k \$

The comparative simulation results of the proposed control and MPPT control [4] are shown in Fig. 6 by solid line and dotted line respectively. Insolation and load are shown in Figs. 6 (a) and (b) respectively. Fig 6(c) shows the PV power produced by MPPT control and proposed control. From, Fig. 6(c), it can be said that PV power produced by proposed method is levelled by battery charging/discharging action. Fig. 6(d) shows diesel power where diesel power produced by proposed method fluctuates less than the diesel power produced by MPPT control. Fig. 6(e) shows the frequency deviations where frequency deviations produced by MPPT control are ± 1 Hz. On the other hand, frequency deviations produced by proposed method is almost near to zero. Therefore, it can be said that the proposed method is effective to reduce the frequency deviation of the utility.

Fig. 6(f) shows battery charging/discharging action. Fig. 6(g) shows the storage energy ratio which is maintained below 50%, thus, it will reduce maintenance cost for the battery. So overall capital cost will be reduced as the optimum battery and inverter capacity is used by the proposed method.

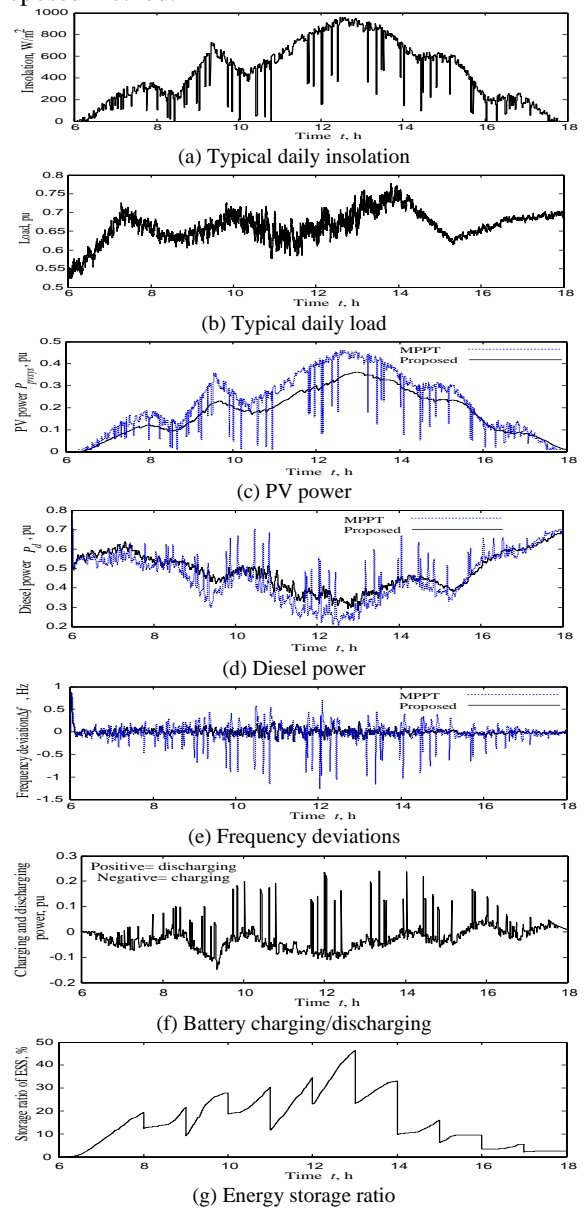


Fig. 6. Comparative simulation results of the proposed control and MPPT control

References

- [1] A. Woyte et. al, "Voltage fluctuations on distribution level introduced by photovoltaic systems," IEEE Trans. Energy Convers., vol. 21, no. 1, pp. 202-209, March 2006.
- [2] T. Kinjo, T. Senjyu, N. Urasaki, and H. Fujita, "Output leveling of renewable energy by electric double layer capacitor applied for energy storage system," IEEE Trans. Energy Convers., vol. 21, no.1, pp. 221- 227, March 2006.
- [4] A. N. Femia et. al., "Optimization of perturb and observe maximum power point tracking method," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 963-973, July 2006.
- [3] T. Senjyu et. al., "A New Method for Smoothing Output Power Fluctuations of PV System Connected to Small Power Utility," presented at the 7th International Conference on Power Electronics, Daegu, Korea, 2007.