Fundamentals for the design of energy management strategies for smart grids based on predictive control techniques. Methodology and case studies

Pajares A.[1*], Vivas F.J.[2], Blasco X.[1], Herrero J.M.[1], Segura F.[2] and Andujar J.M.[2]

[1] *Instituto Universitario de Automática e Informática Industrial, Universitat Politècnica de València, Valencia, Spain*
[2] *Research Centre on Technology, Energy and Sustainability (CITES), University of Huelva, Spain*

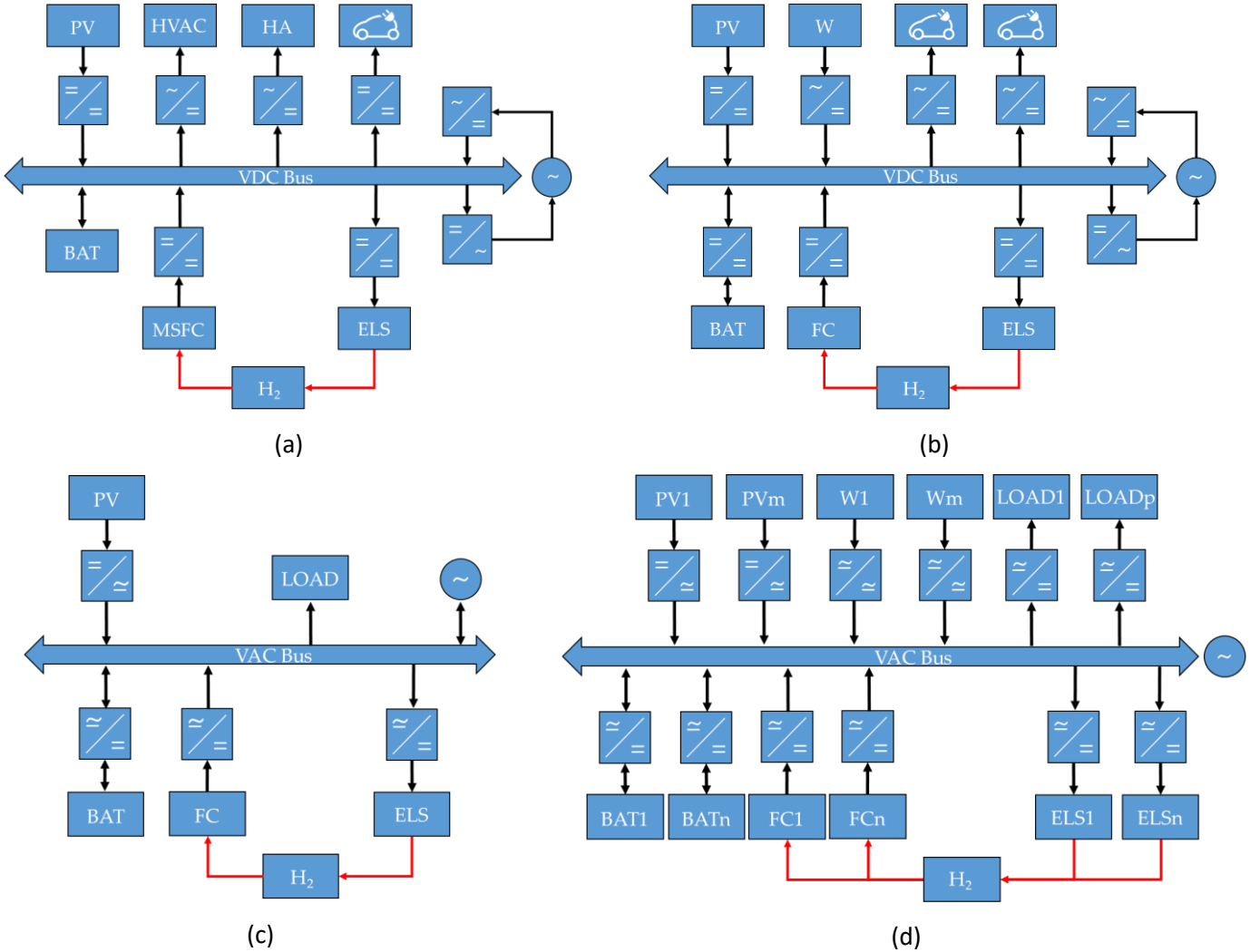

Fig. 1. Microgrid architecture for: (a) residential application (case 1); (b) electric vehicle charging station application (case 2); (c) industrial application (case 3); and (d) community application (case 4).

*alpafer1@upv.es

Symbols

PH	Prediction horizon (h)	$Cost_{MPC}$	Economic cost of the MPC-based EMS considering microgrid architecture (€)
T_s	Sample time (h)	$Cost_{MPC}^{BSS}$	Economic cost of the MPC-based EMS considering microgrid architecture without hydrogen system (€)
SOC_{bat}^{ini}	Initial battery state of charge (%)	$Cost_{ren}$	Economic cost considering microgrid architecture without energy storage systems (€)
SOC_{H2}^{ini}	Initial hydrogen state of charge (%)	$Cost_{ren}^{PV}$	Economic cost considering microgrid architecture without energy storage systems and without wind turbine (€)
V_{BUS}^{ini}	Initial bus voltage (V)	$Cost_{MEG}$	Economic cost traditional case based on the exclusive connection to the main electrical grid (€)

This document compiles all the simulations performed to validate the EMS developed in the paper. Details of the development and discussion of results can be found in the paper[1] (if used please cite article). Tests have been performed for different microgrid architectures (see Fig. 1) and in various scenarios (see summary Table 1, Table 2, Table 3 and Table 4).

[1]**Fundamentals for the design of energy management strategies for smart grids based on predictive control techniques. Methodology and case studies**

1. Microgrid architecture for residential application (case 1, Fig. 1).

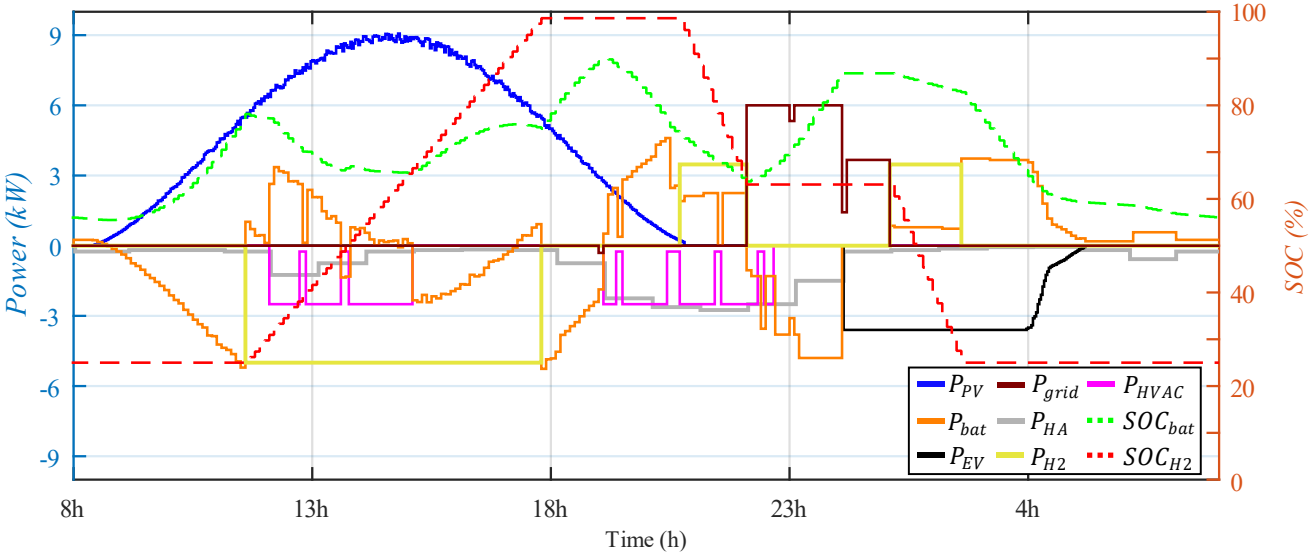

Fig. 1. 1. Power and SOC profiles obtained for scenarios 1 and residential application.

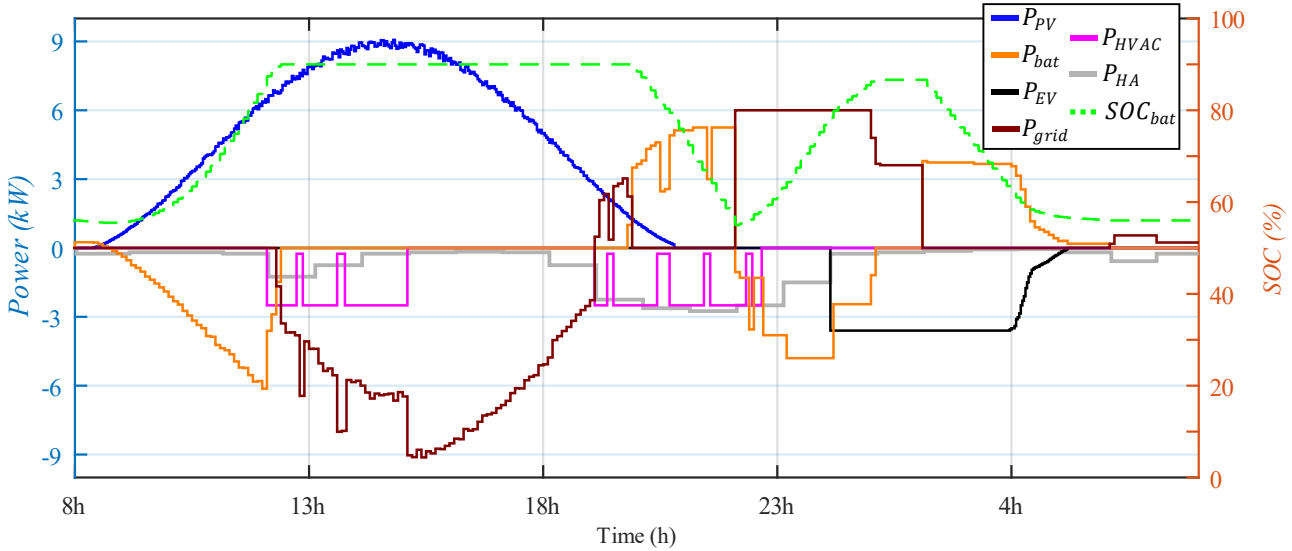

Fig. 1. 2. Power and SOC profiles obtained for scenarios 1 and residential application.

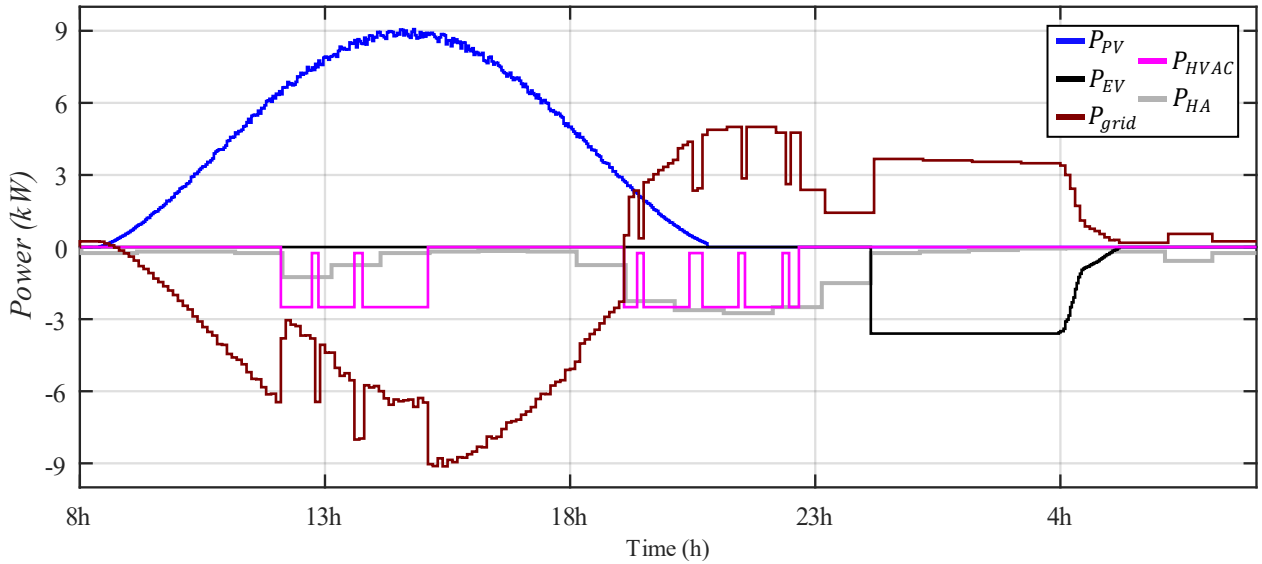

Fig. 1. 3. Power and SOC profiles obtained for scenario 1 and 2 and residential application.

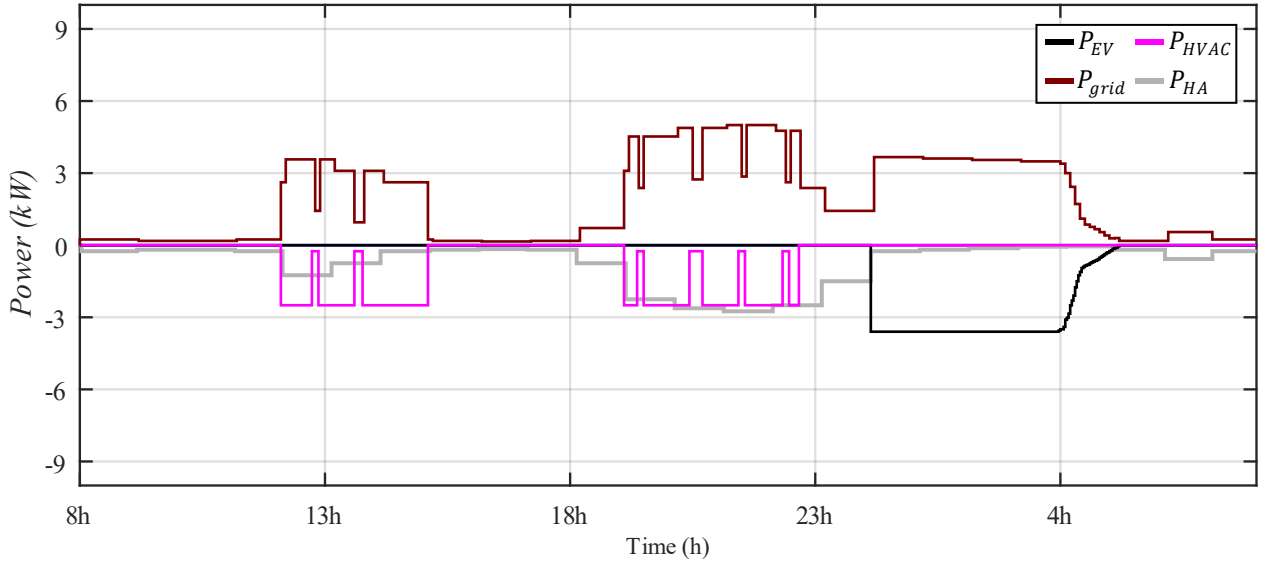

Fig. 1. 4. Power and SOC profiles obtained for scenario 1, 2, 8, 9, 15 and 16 and residential application.

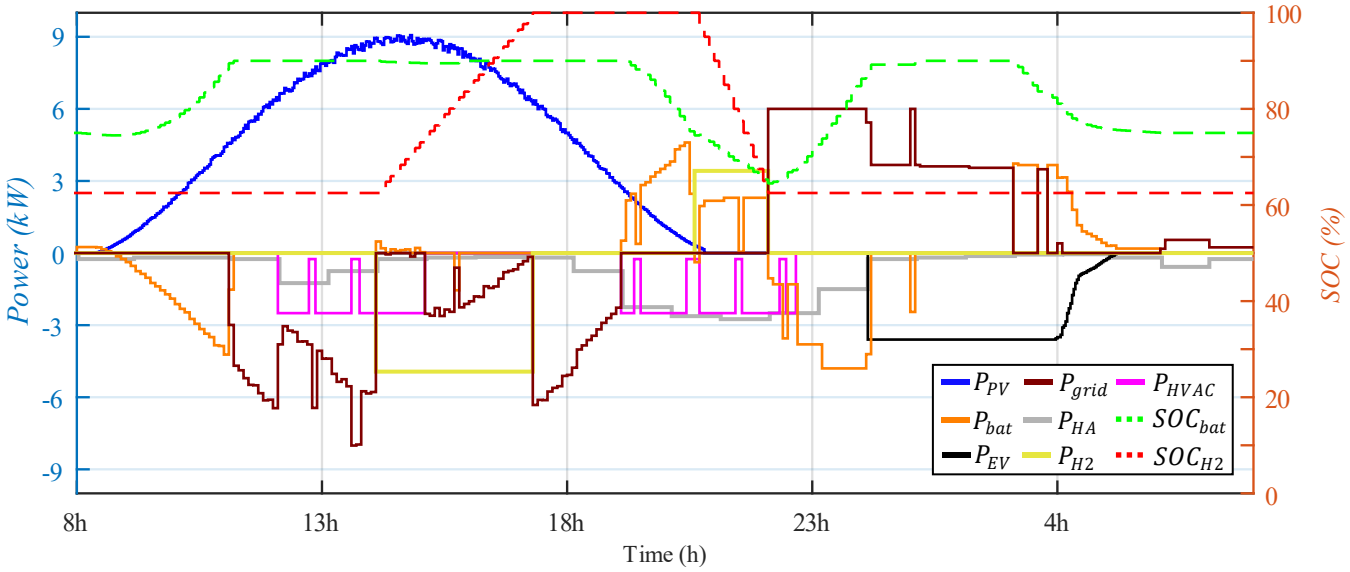

Fig. 1. 5. Power and SOC profiles obtained for scenario 2 and residential application.

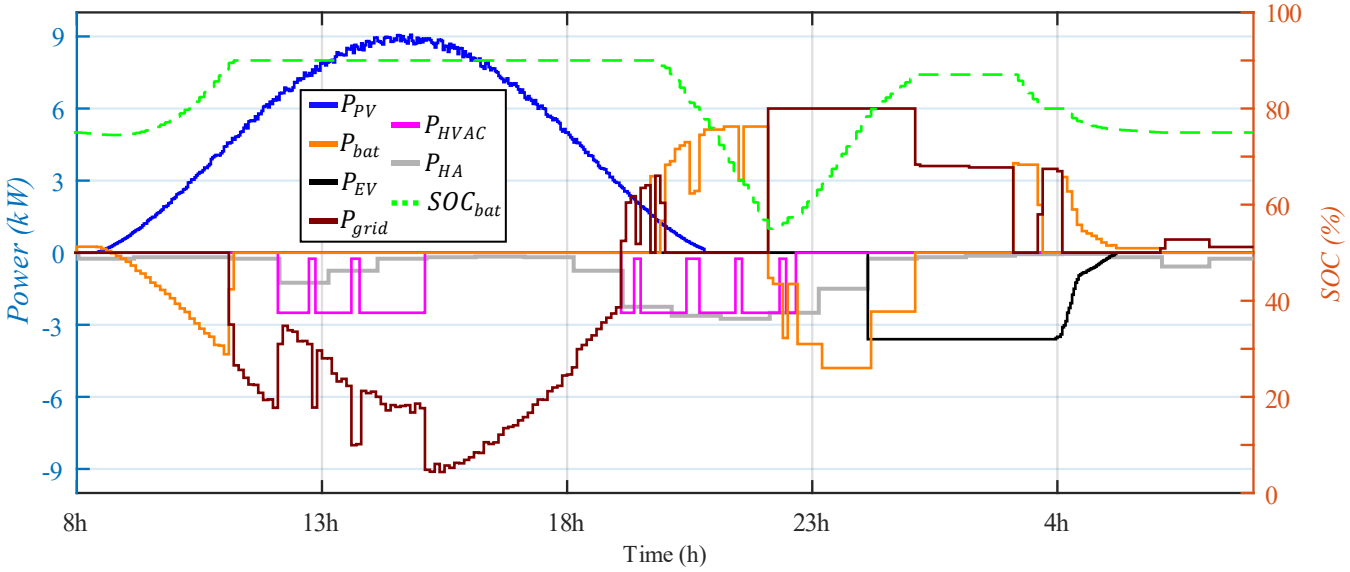

Fig. 1. 6. Power and SOC profiles obtained for scenario 2 and residential application.

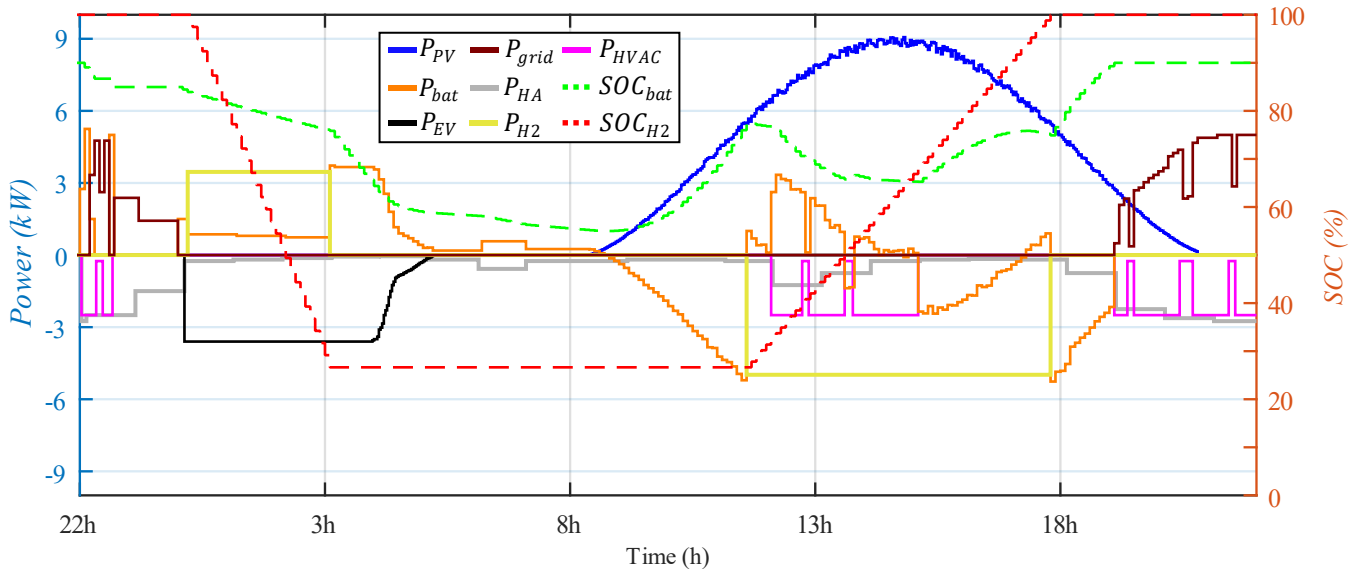

Fig. 1. 7. Power and SOC profiles obtained for scenario 3 and residential application.

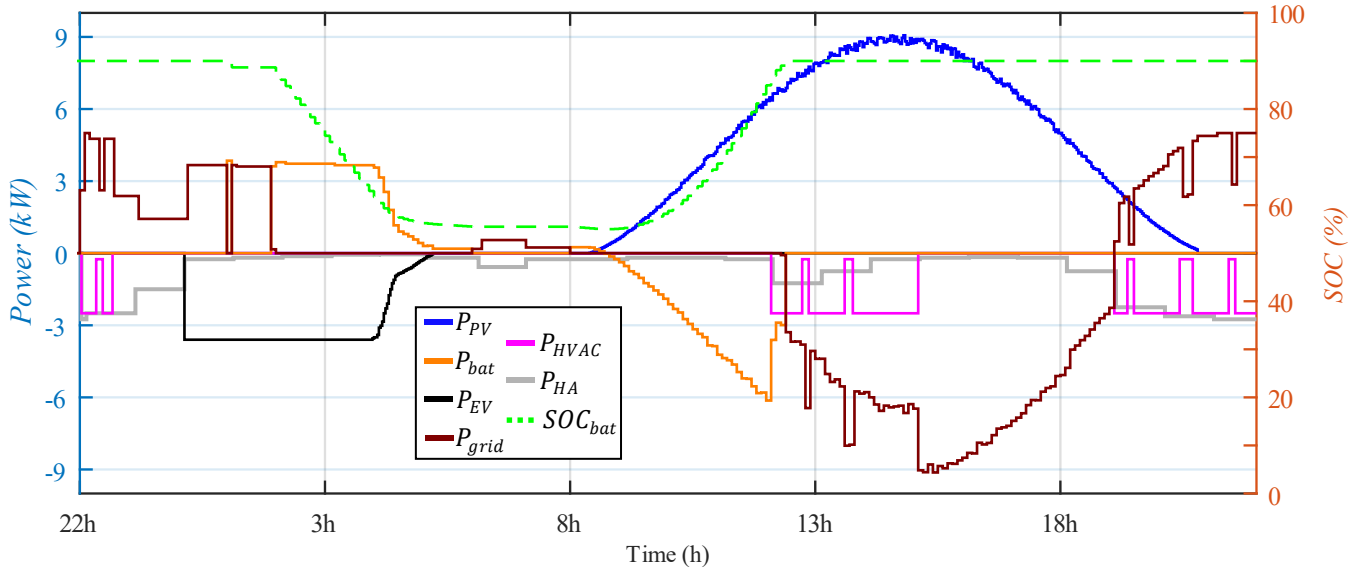

Fig. 1. 8. Power and SOC profiles obtained for scenario 3 and residential application.

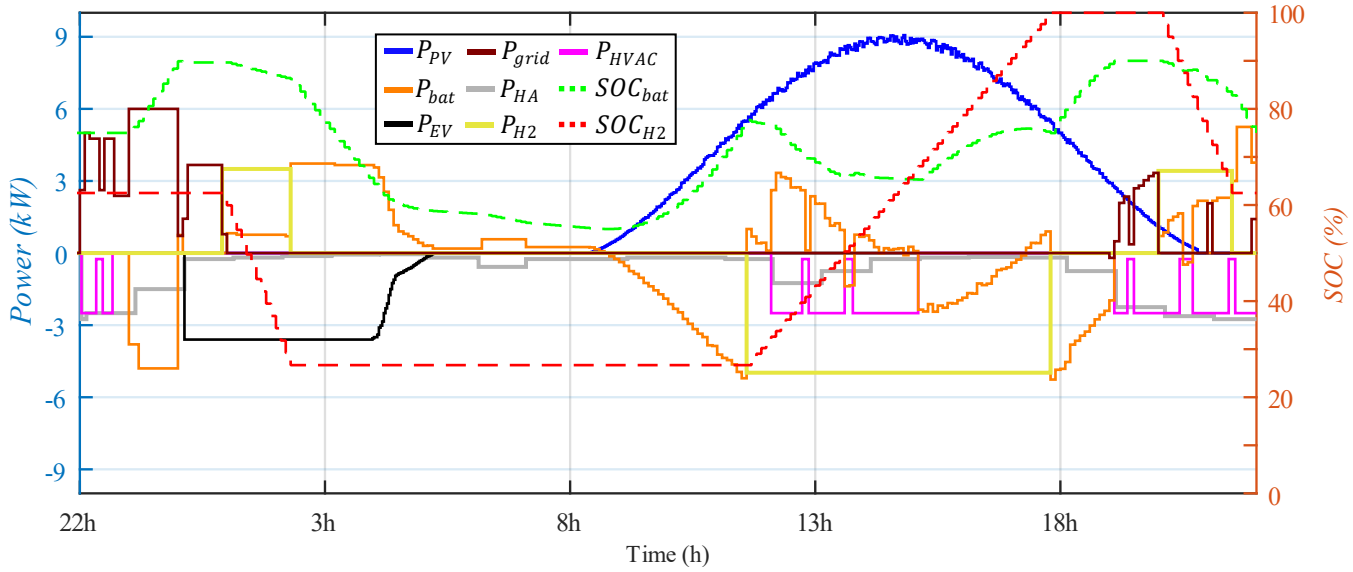

Fig. 1. 9. Power and SOC profiles obtained for scenario 4 and residential application.

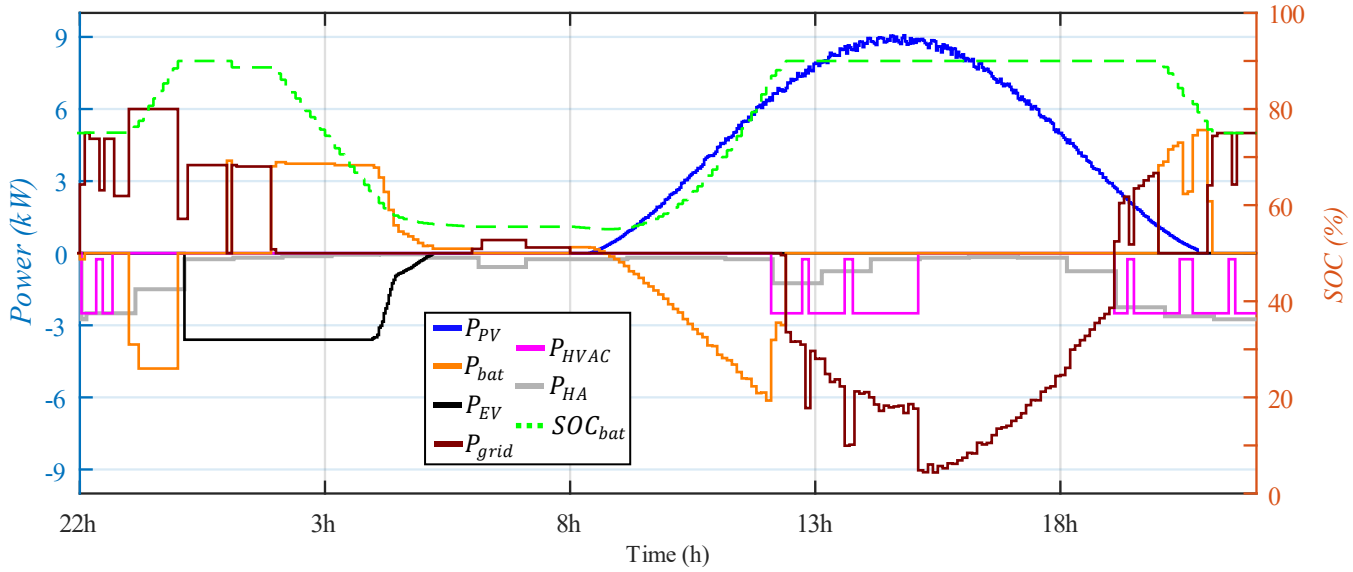

Fig. 1. 10. Power and SOC profiles obtained for scenario 4 and residential application.

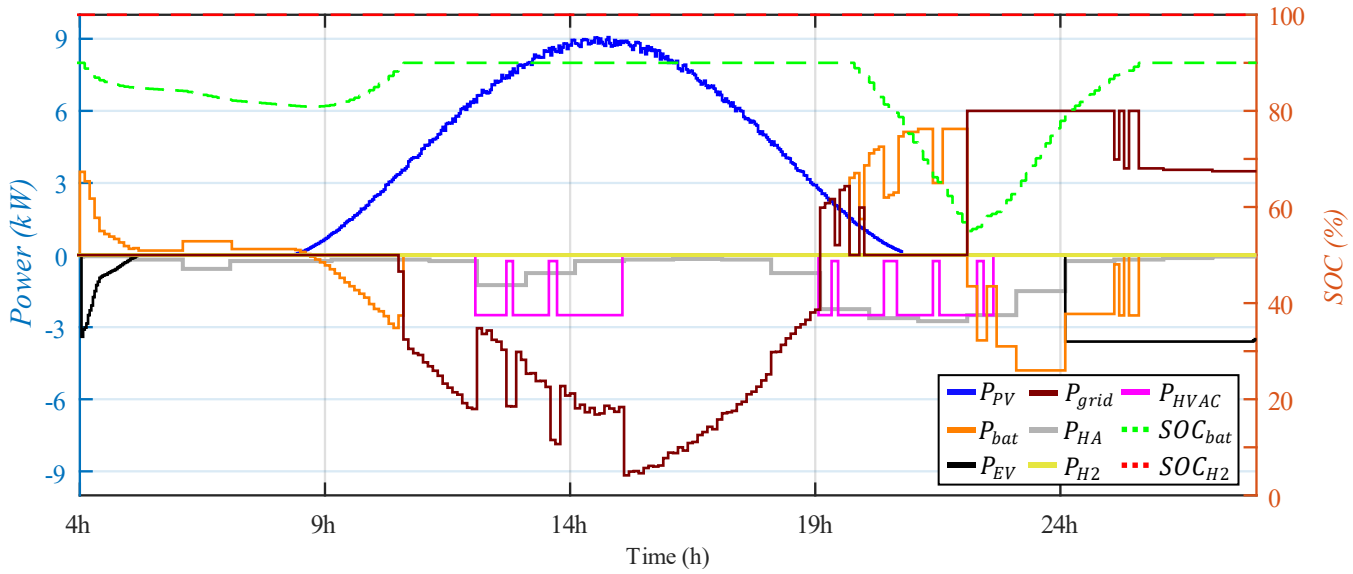

Fig. 1. 11. Power and SOC profiles obtained for scenario 5 and residential application.

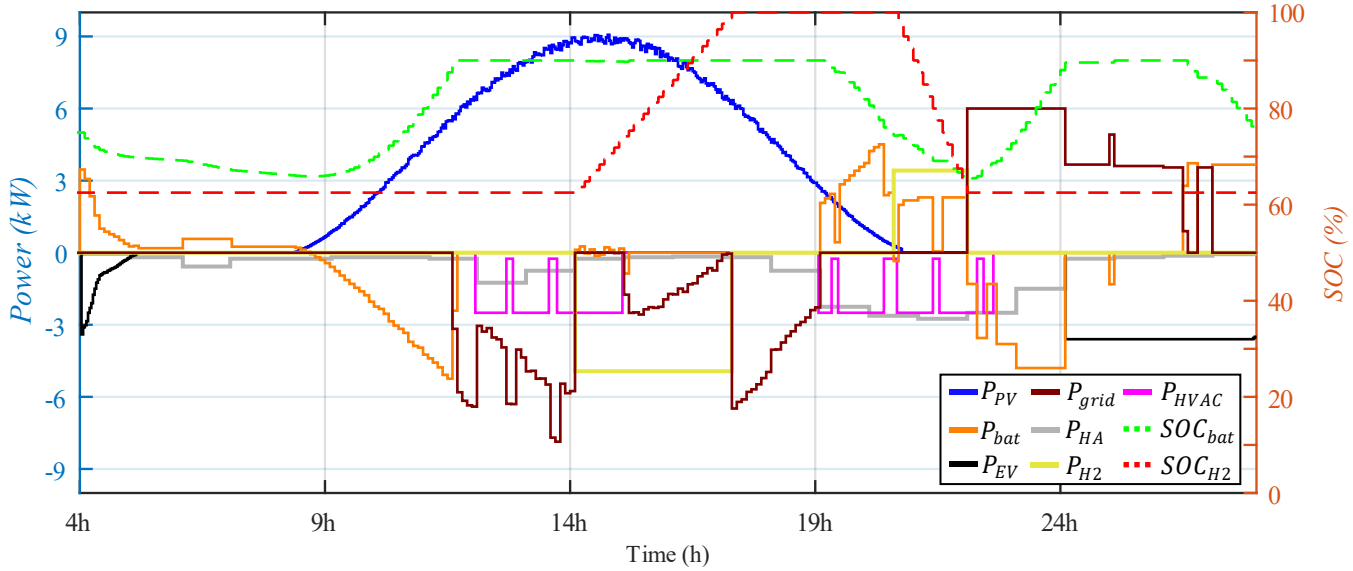

Fig. 1. 12. Power and SOC profiles obtained for scenario 6 and residential application.

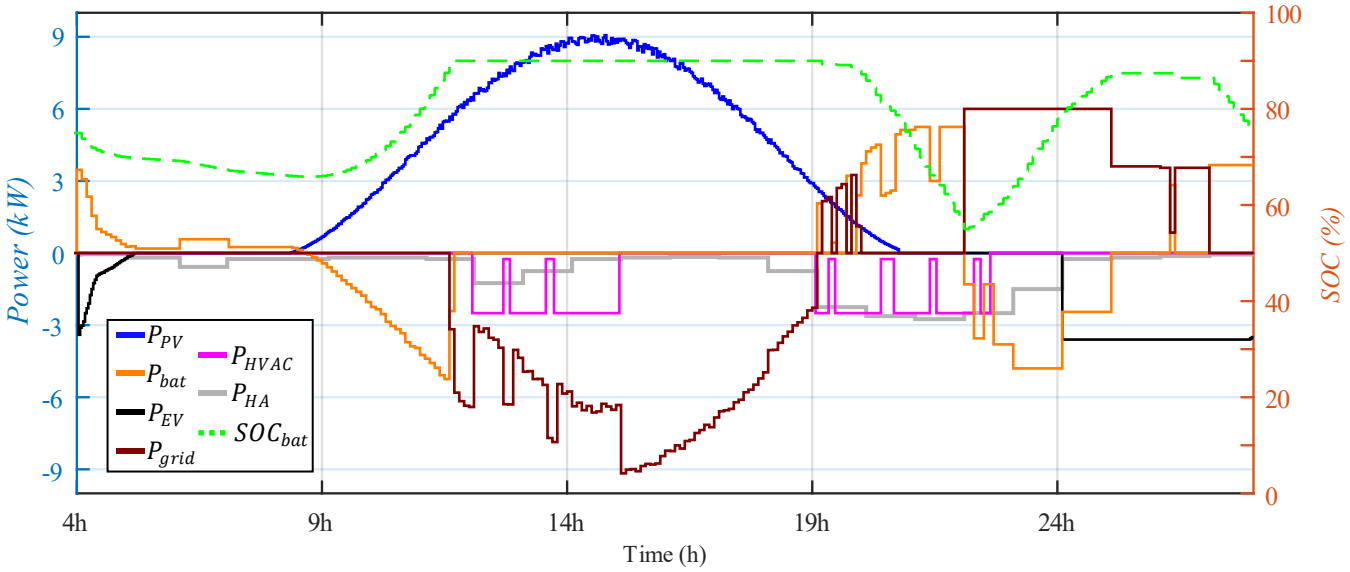

Fig. 1. 13. Power and SOC profiles obtained for scenario 6 and residential application.

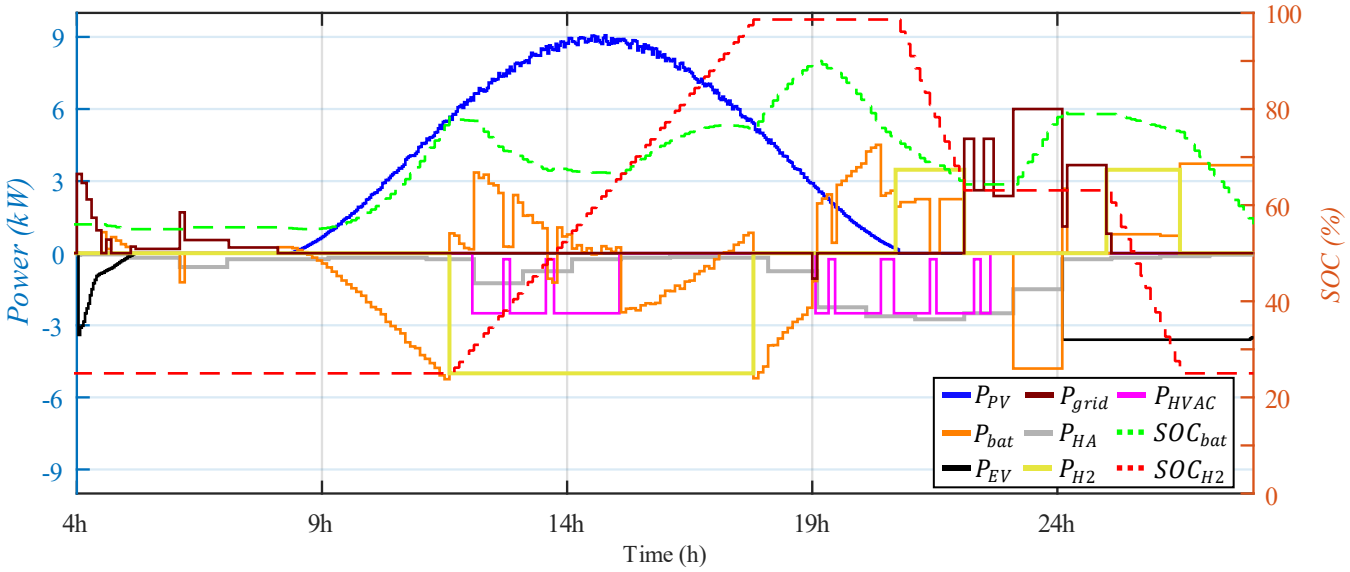

Fig. 1. 14. Power and SOC profiles obtained for scenario 7 and residential application.

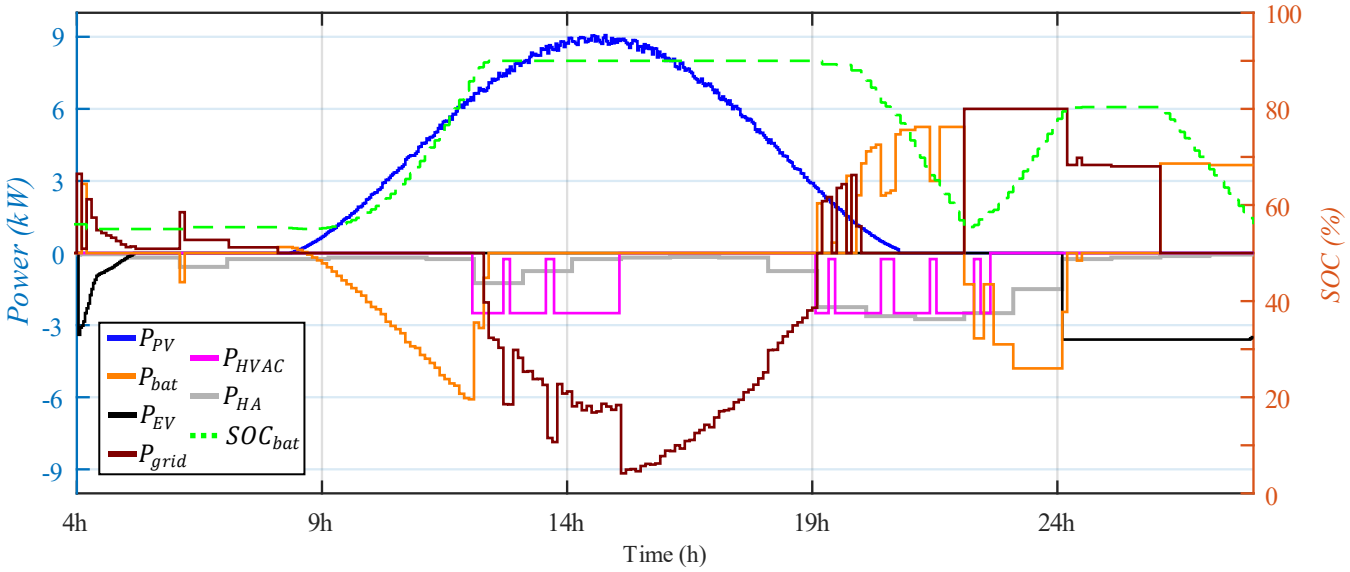

Fig. 1. 15. Power and SOC profiles obtained for scenario 7 and residential application.

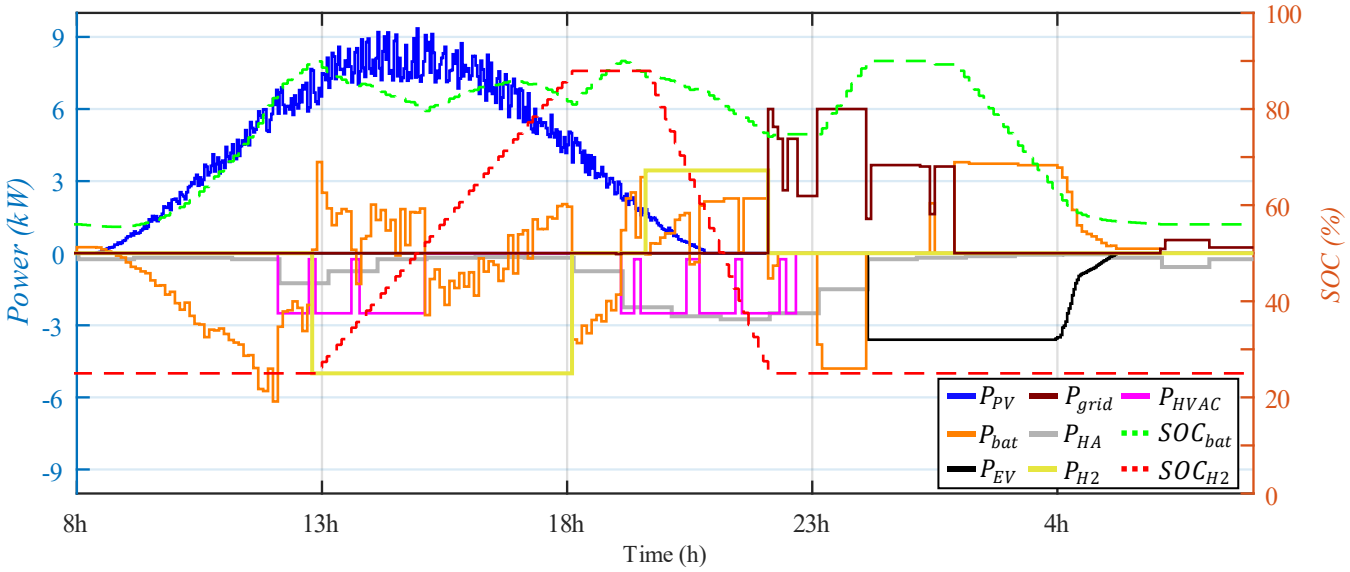

Fig. 1. 16. Power and SOC profiles obtained for scenario 8 and residential application.

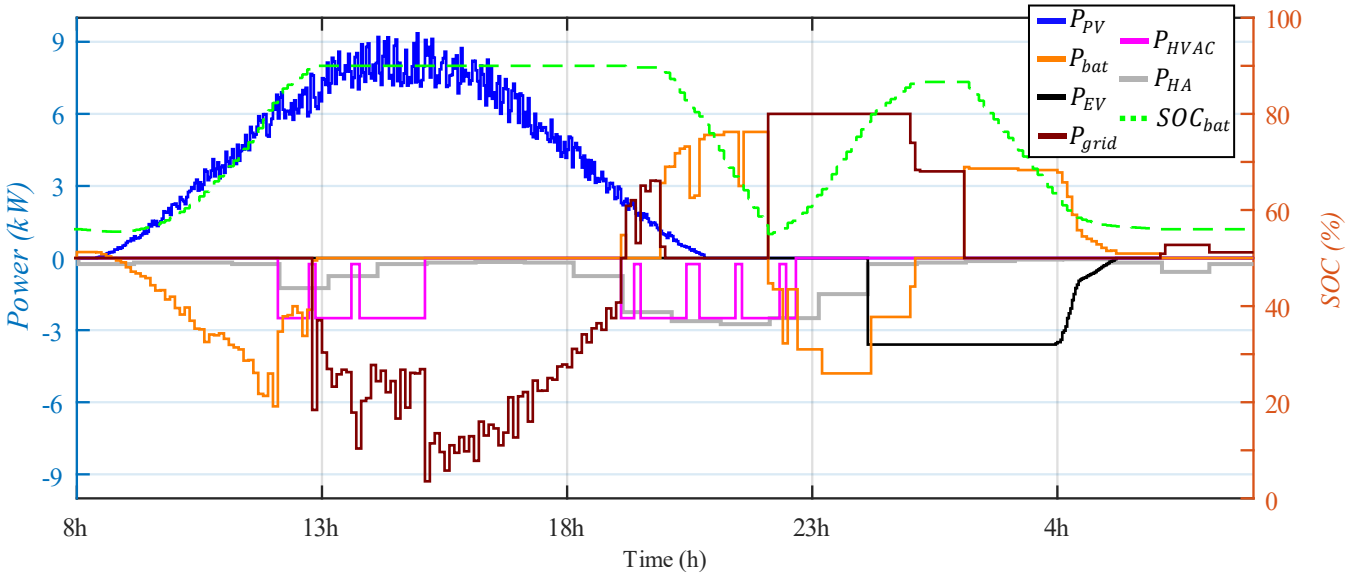

Fig. 1. 17. Power and SOC profiles obtained for scenario 8 and residential application.

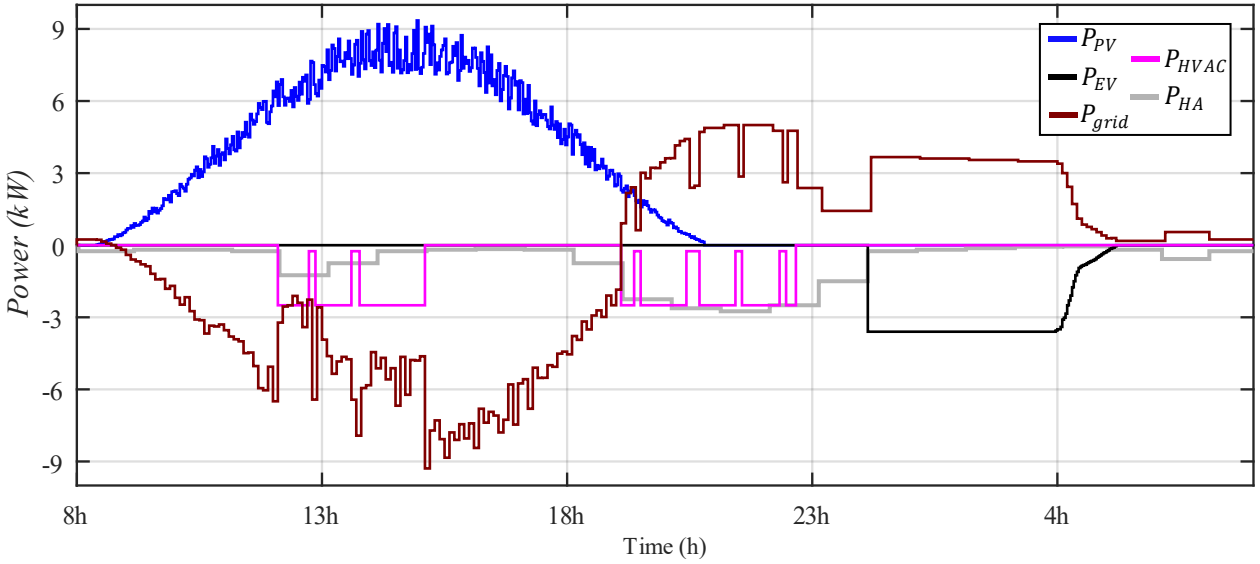

Fig. 1. 18. Power and SOC profiles obtained for scenario 8 and 9 and residential application.

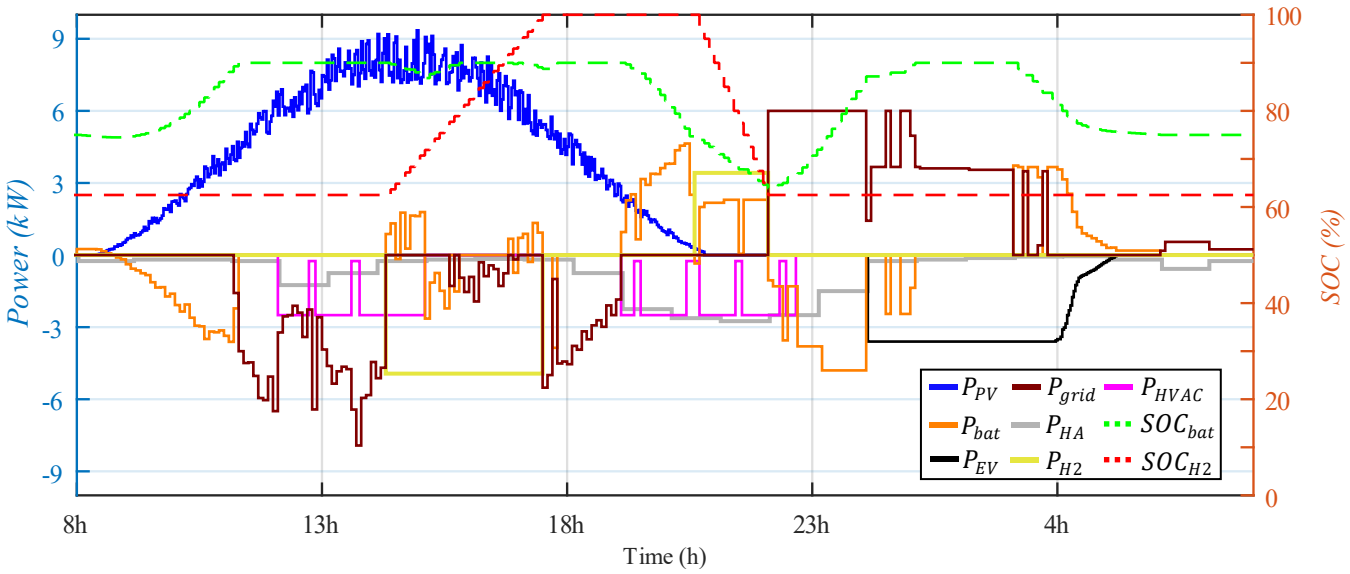

Fig. 1. 19. Power and SOC profiles obtained for scenario 9 and residential application.

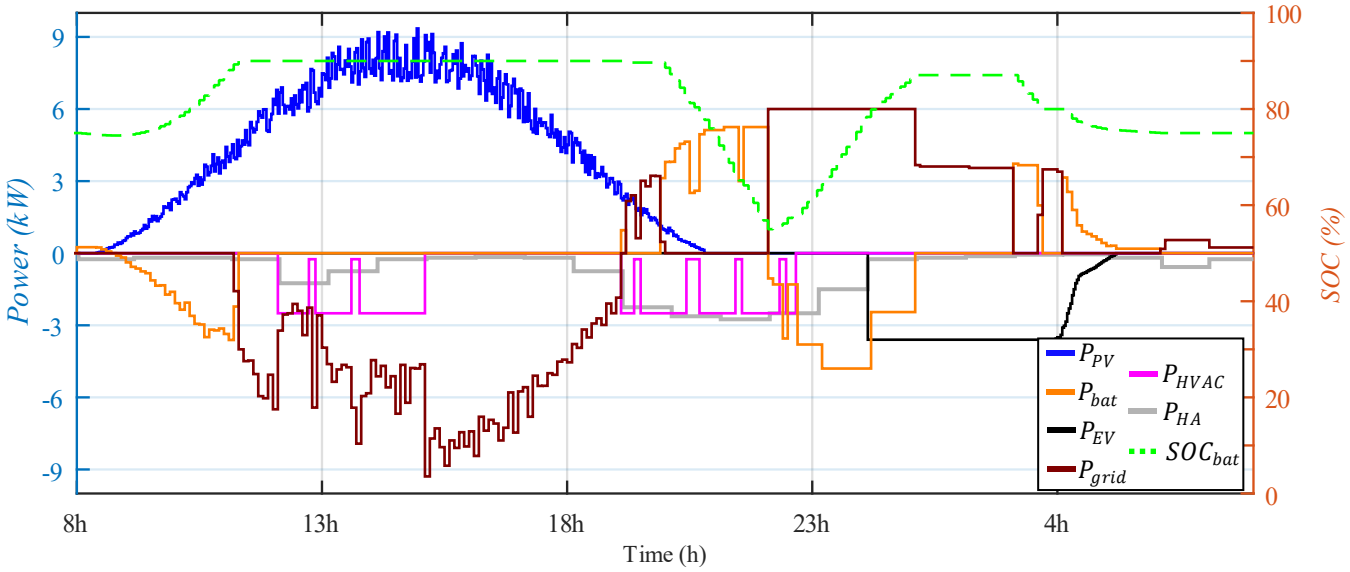

Fig. 1. 20. Power and SOC profiles obtained for scenario 9 and residential application.

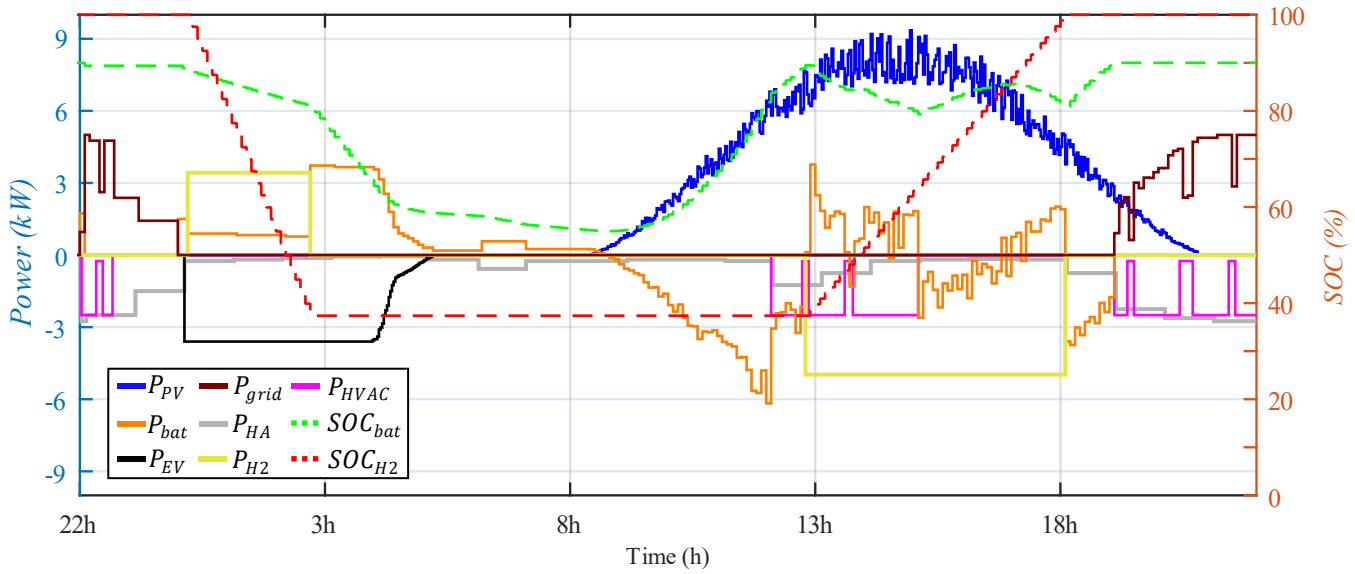

Fig. 1. 21. Power and SOC profiles obtained for scenario 10 and residential application.

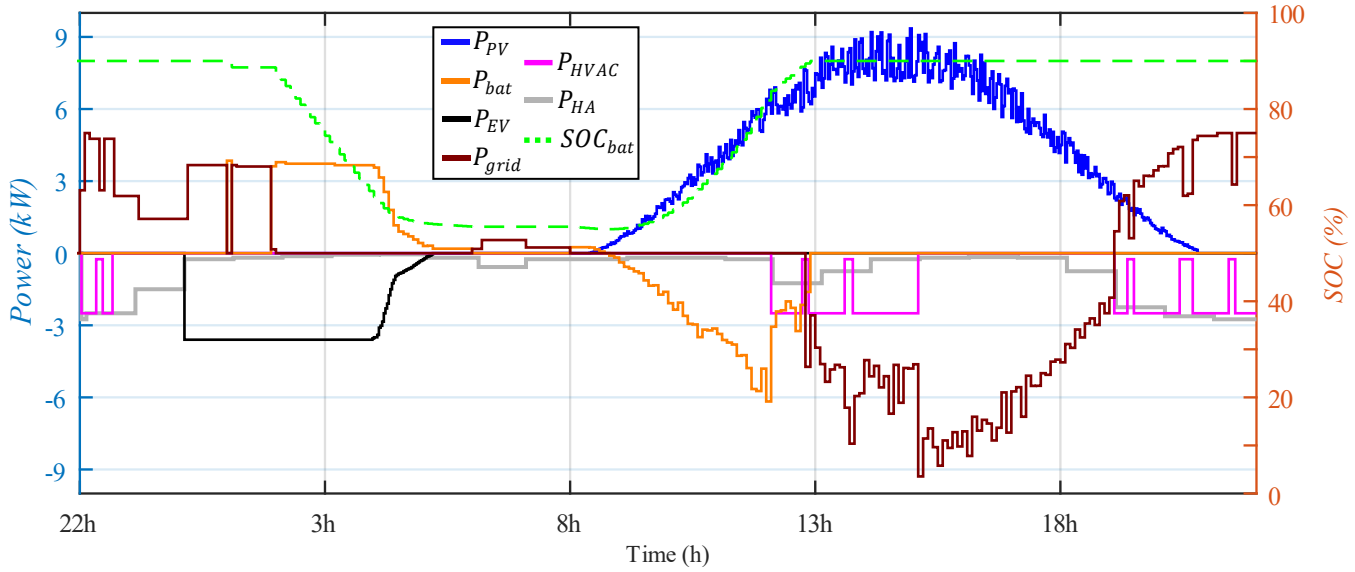

Fig. 1. 22. Power and SOC profiles obtained for scenario 10 and residential application.

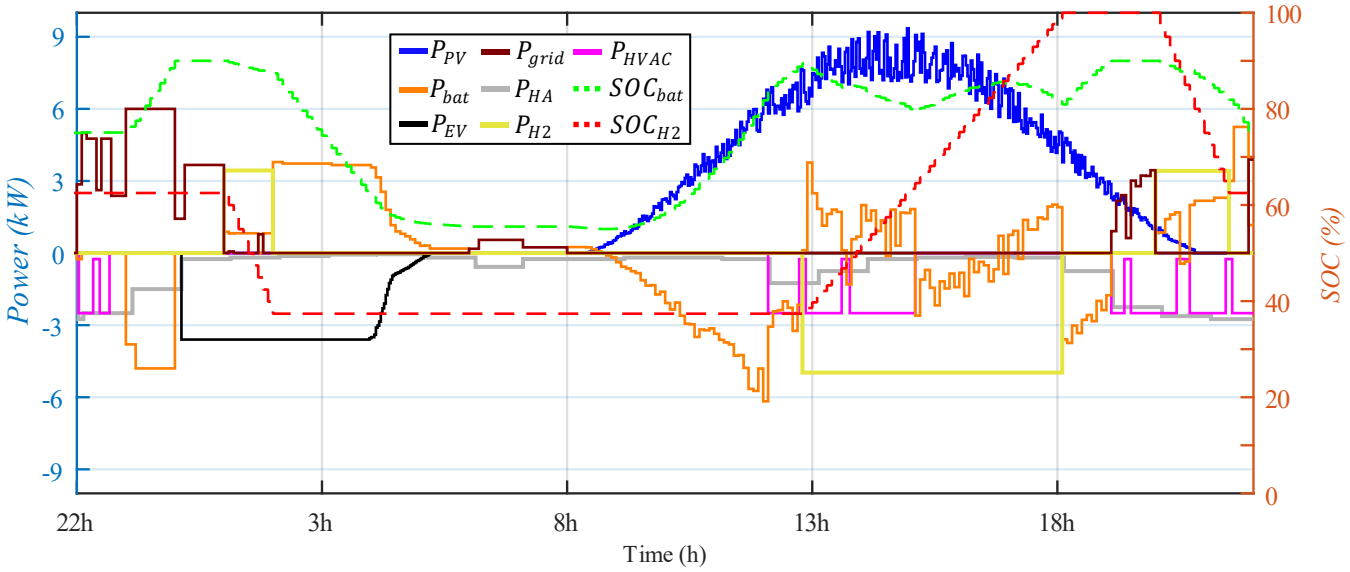

Fig. 1. 23. Power and SOC profiles obtained for scenario 11 and residential application.

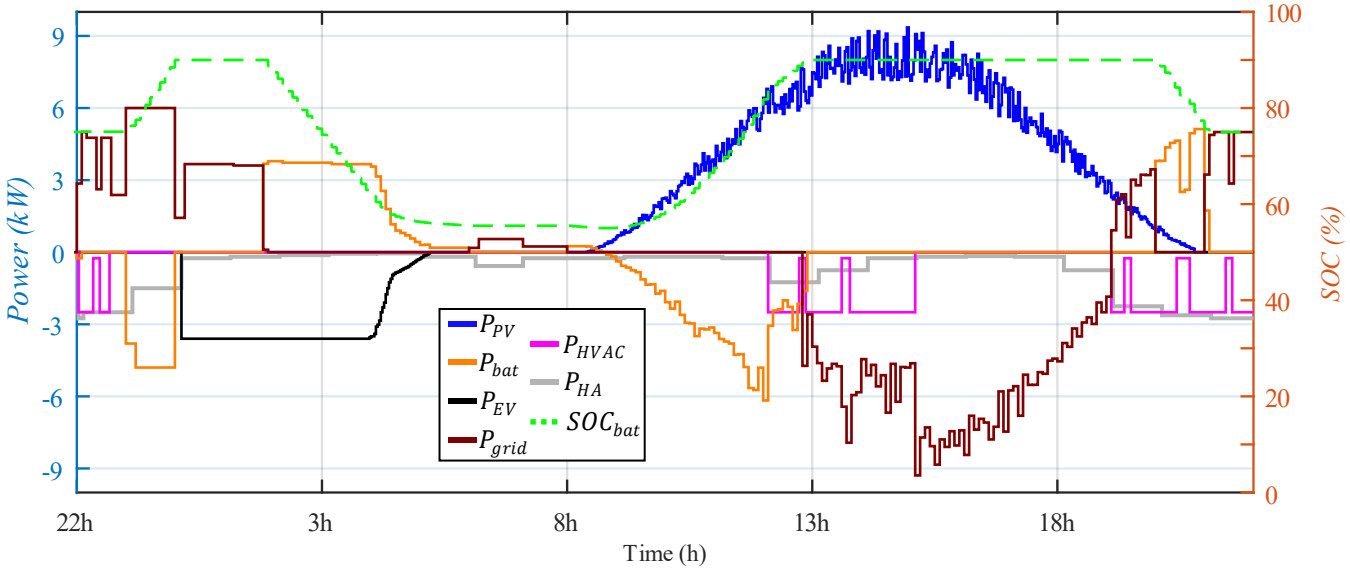

Fig. 1. 24. Power and SOC profiles obtained for scenario 11 and residential application.

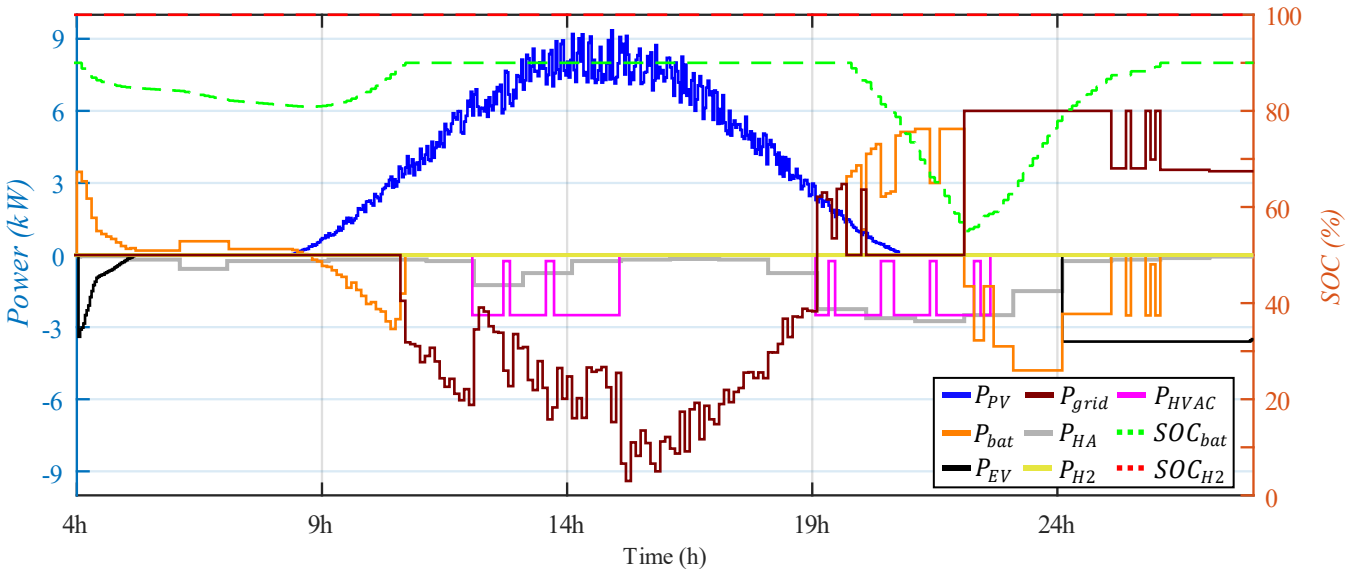

Fig. 1. 25. Power and SOC profiles obtained for scenario 12 and residential application.

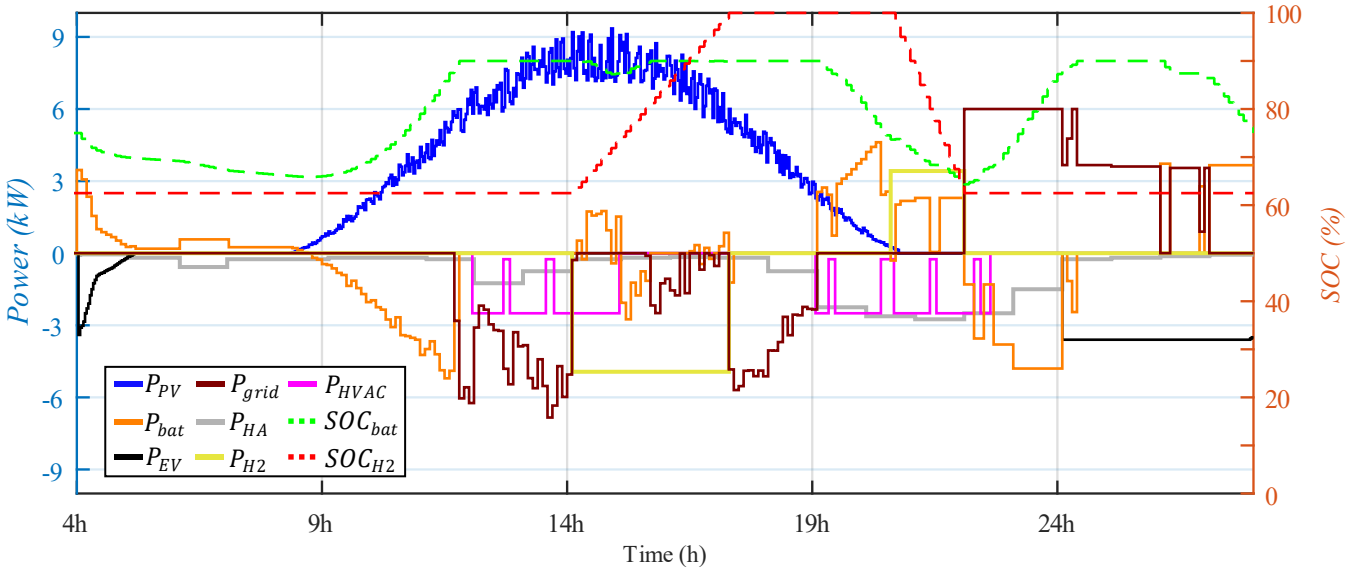

Fig. 1. 26. Power and SOC profiles obtained for scenario 13 and residential application.

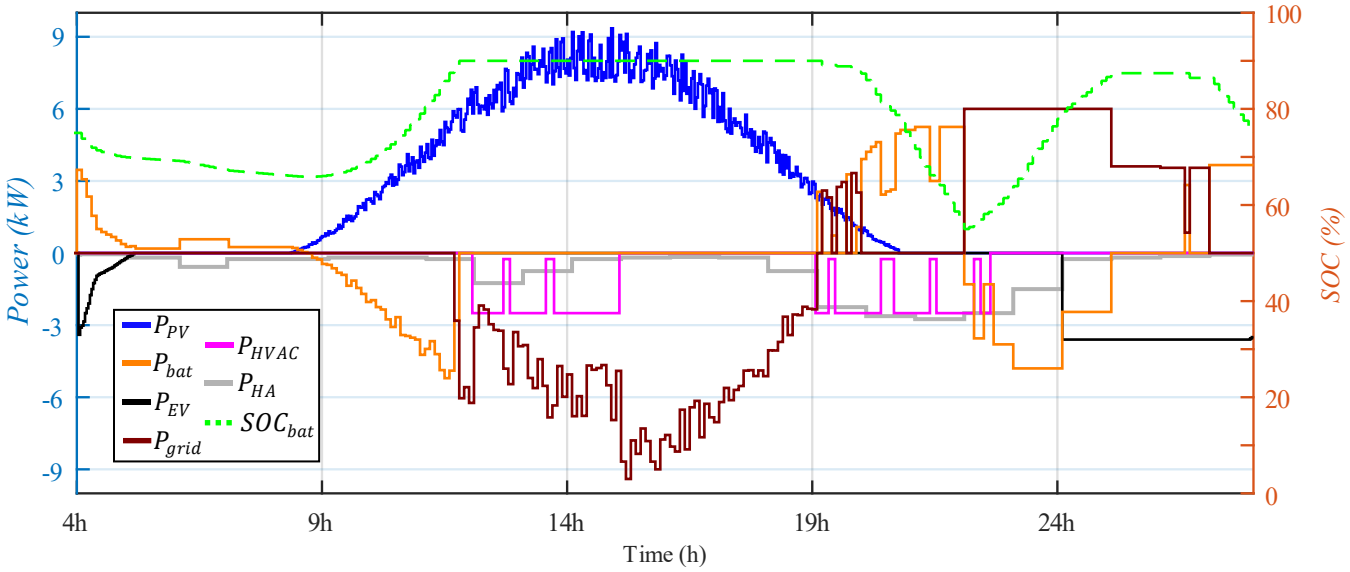

Fig. 1. 27. Power and SOC profiles obtained for scenario 13 and residential application.

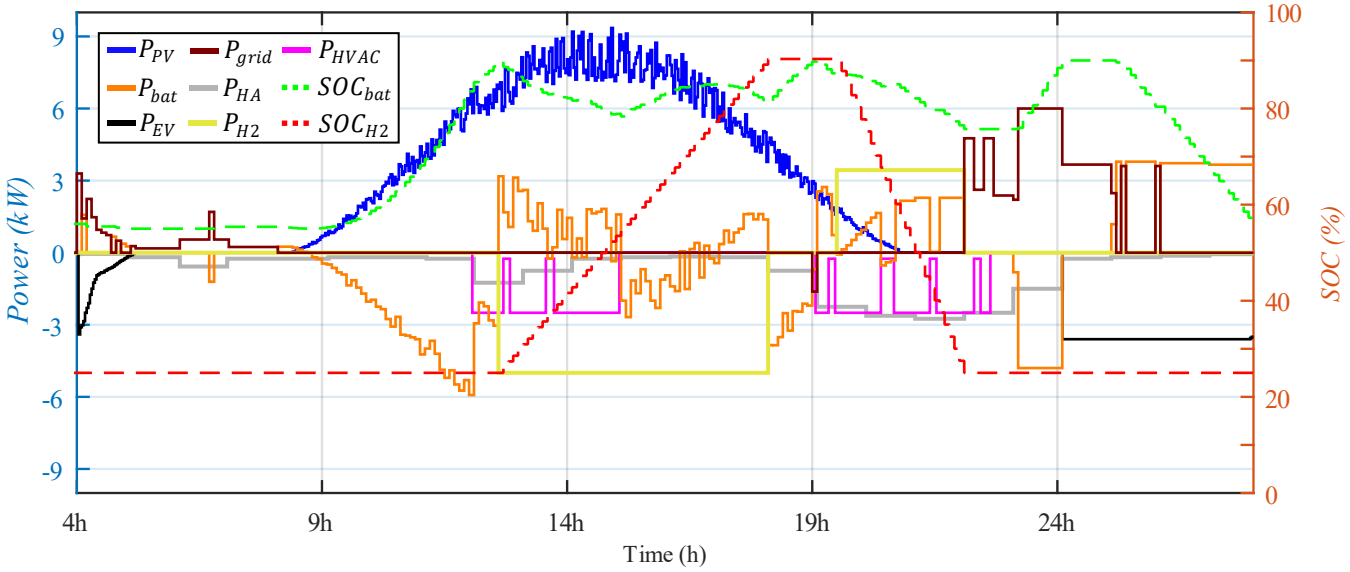

Fig. 1. 28. Power and SOC profiles obtained for scenario 14 and residential application.

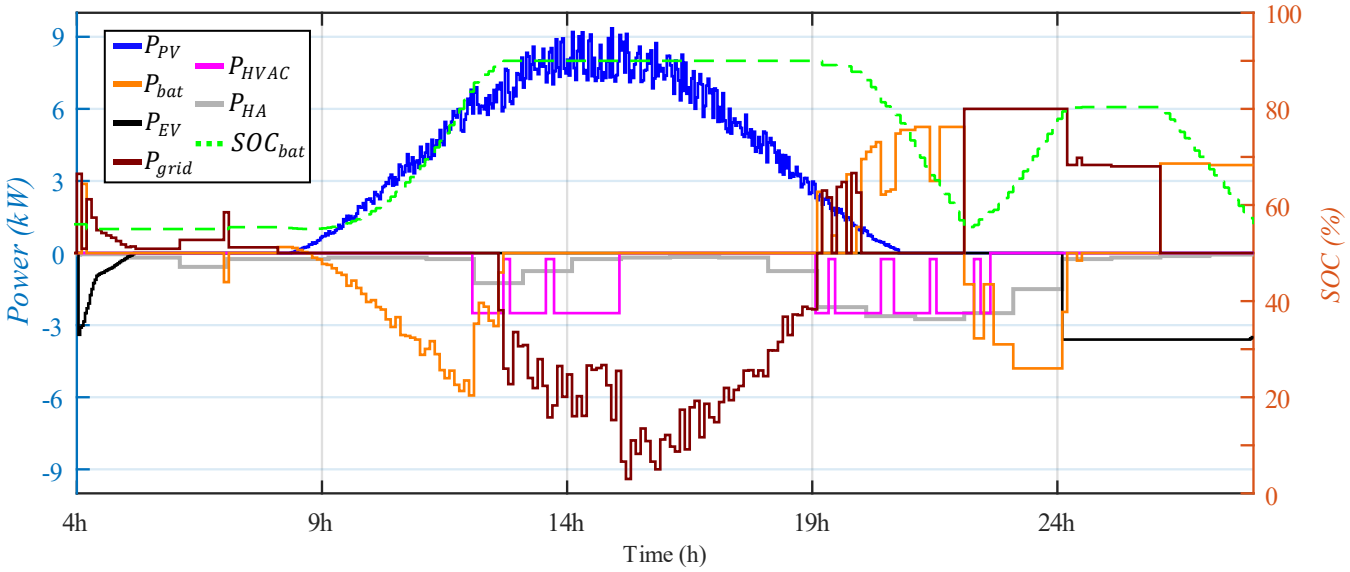

Fig. 1. 29. Power and SOC profiles obtained for scenario 14 and residential application.

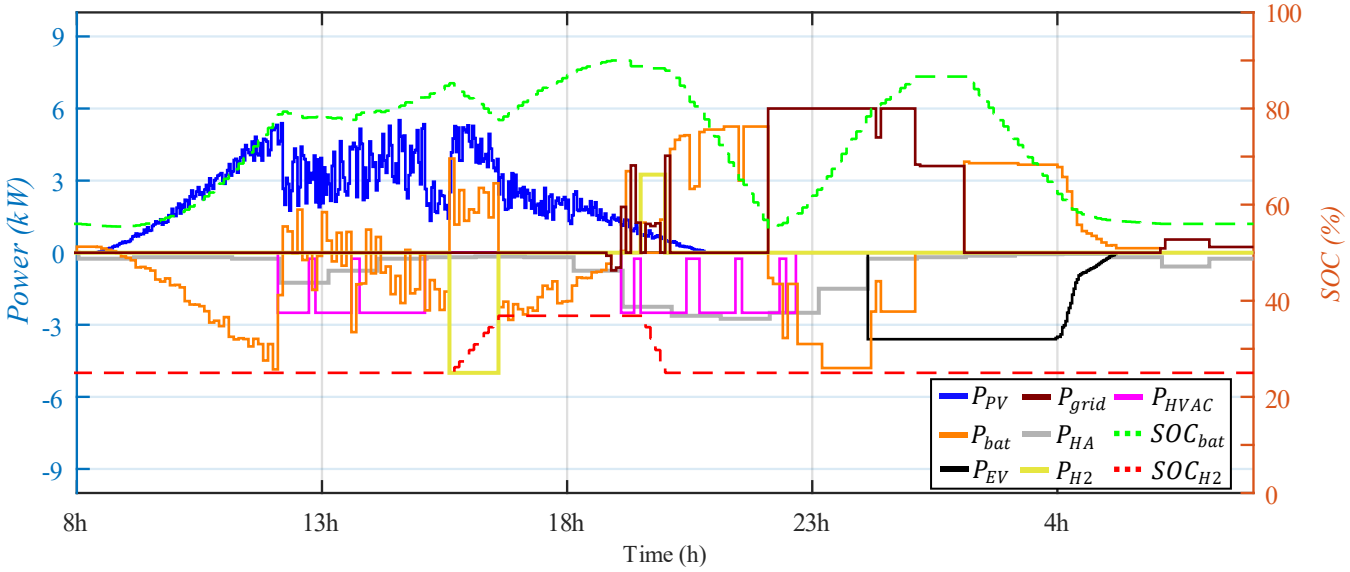

Fig. 1. 30. Power and SOC profiles obtained for scenario 15 and residential application.

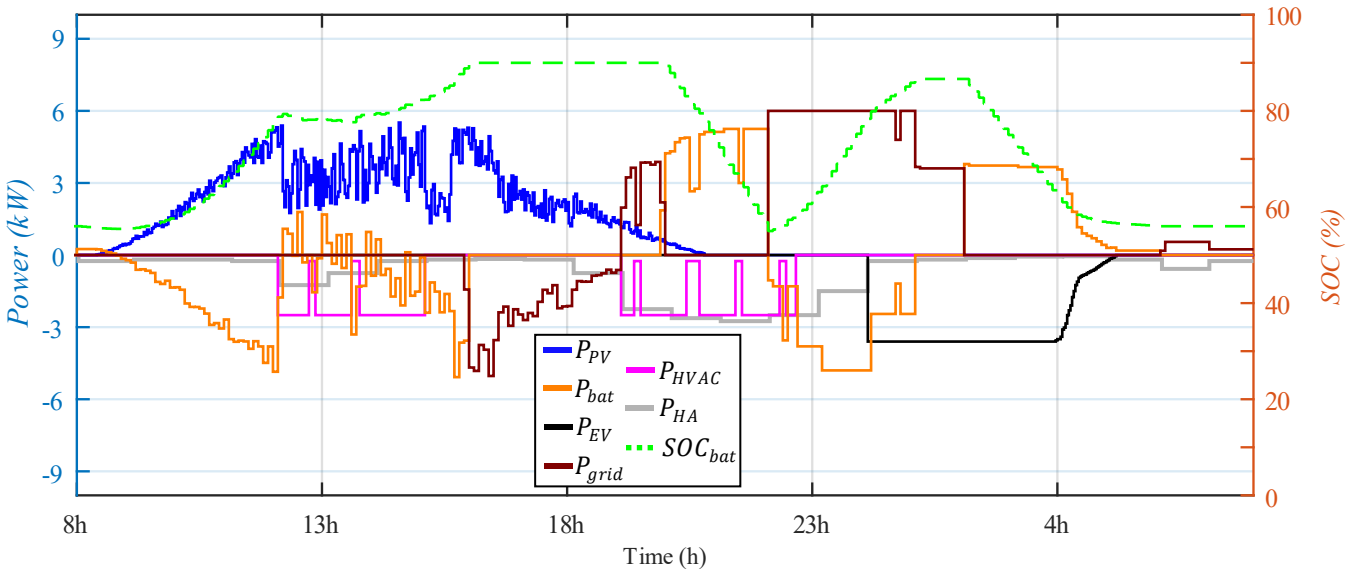

Fig. 1. 31. Power and SOC profiles obtained for scenario 15 and residential application.

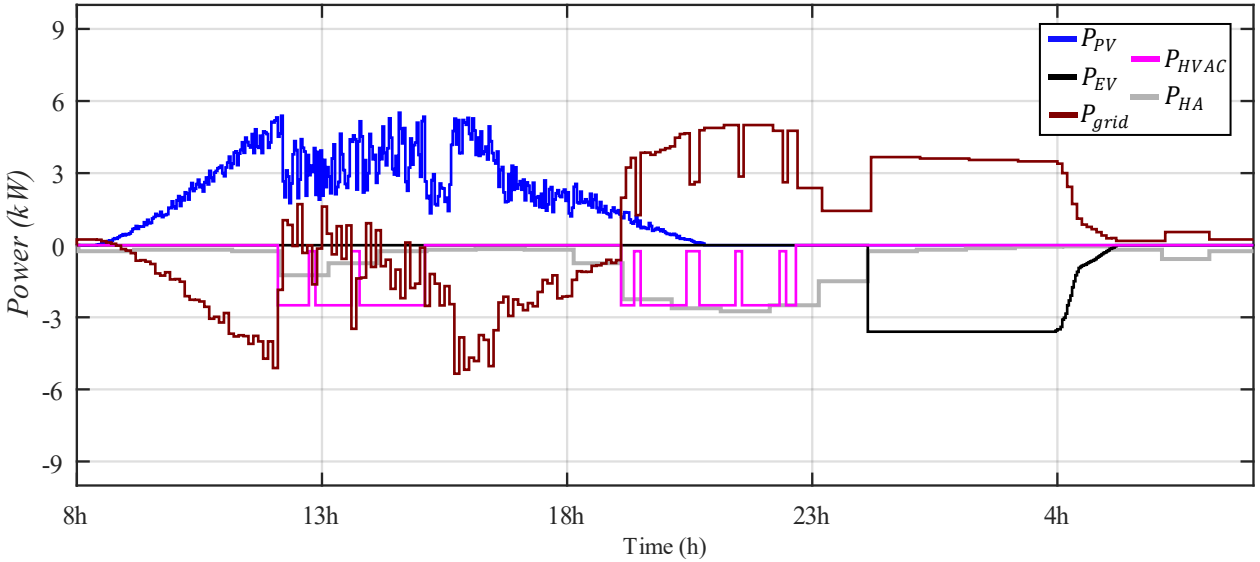

Fig. 1. 32. Power and SOC profiles obtained for scenario 15 and 16 and residential application.

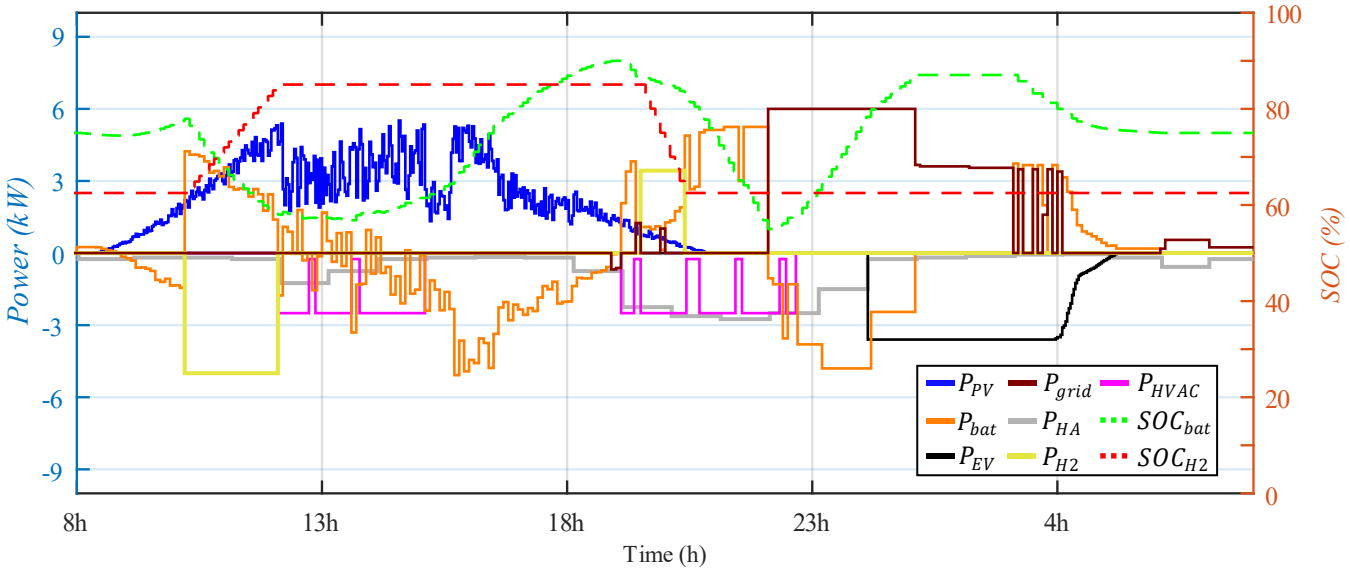

Fig. 1. 33. Power and SOC profiles obtained for scenario 16 and residential application.

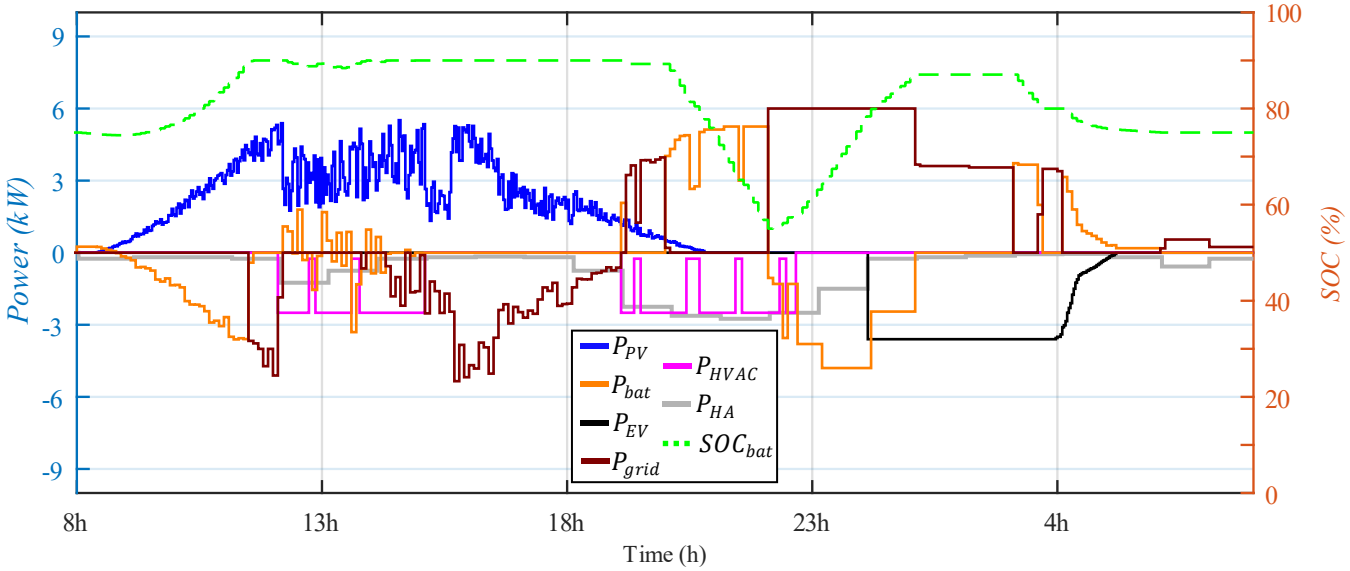

Fig. 1. 34. Power and SOC profiles obtained for scenario 16 and residential application.

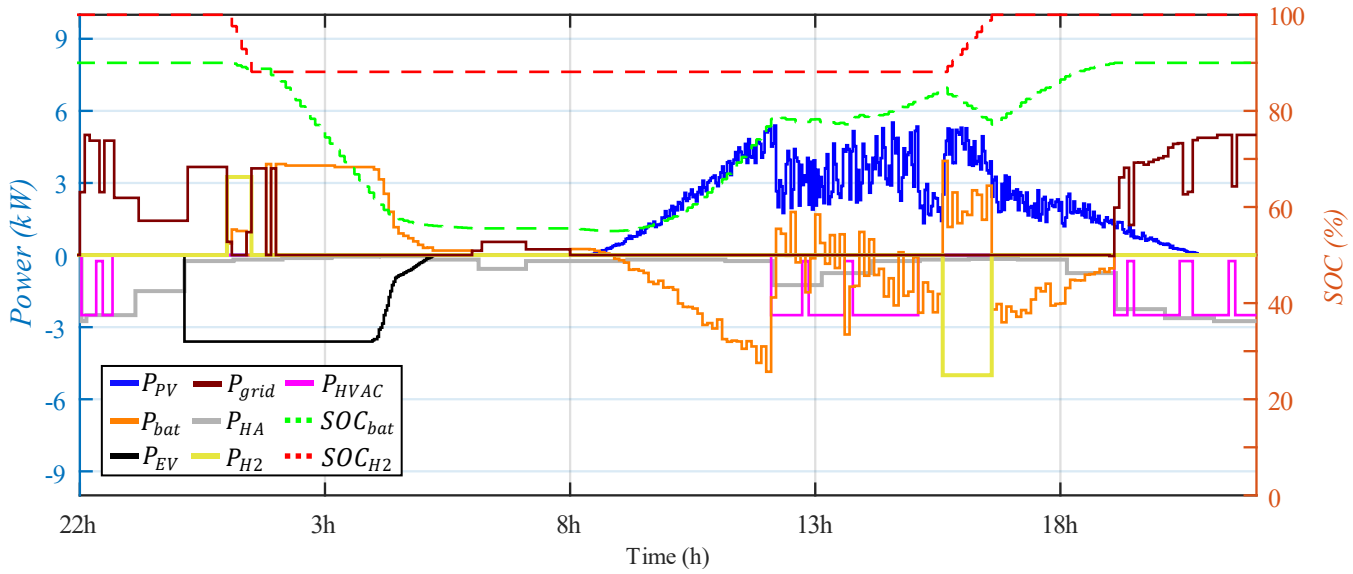

Fig. 1. 35. Power and SOC profiles obtained for scenario 17 and residential application.

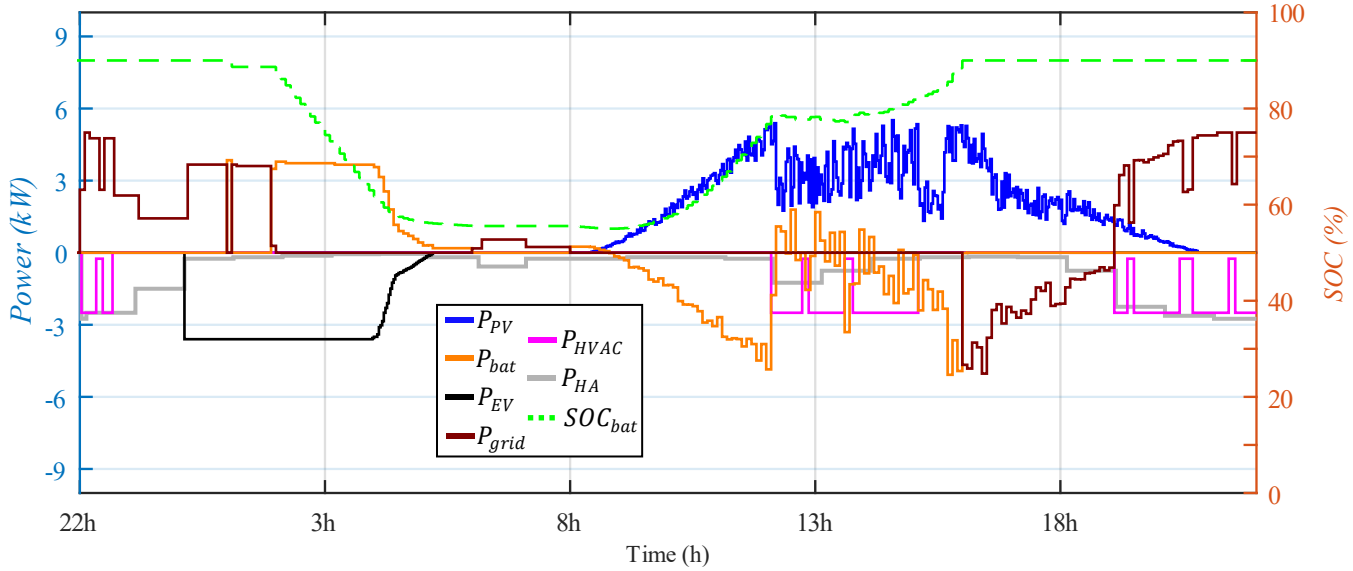

Fig. 1. 36. Power and SOC profiles obtained for scenario 17 and residential application.

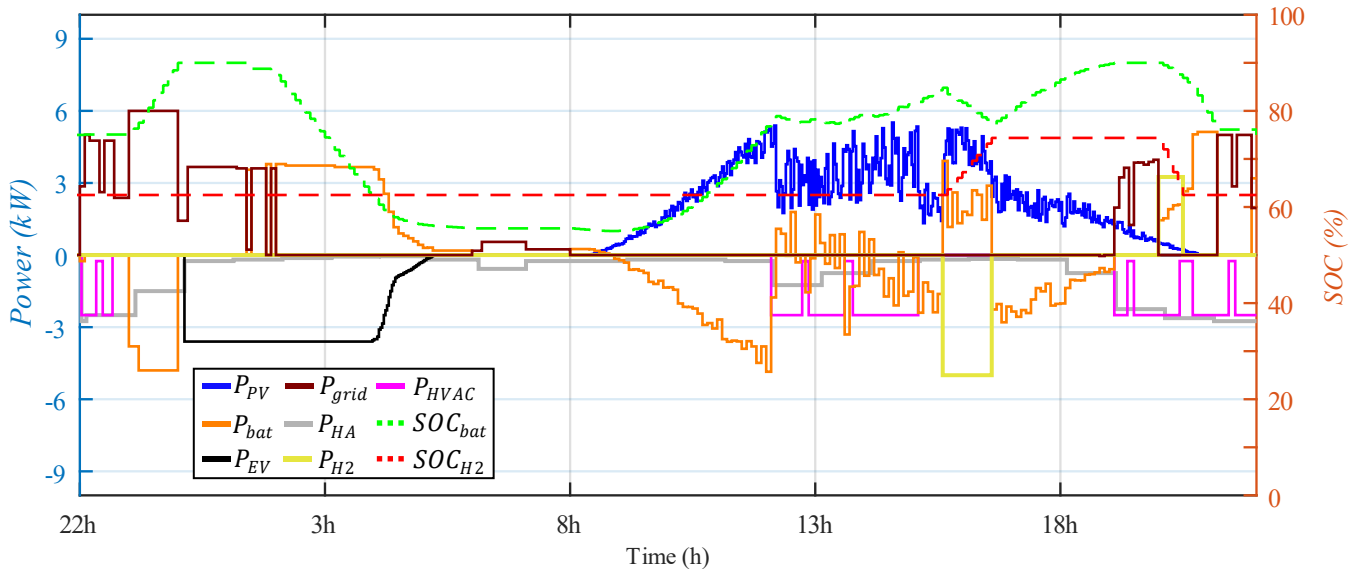

Fig. 1. 37. Power and SOC profiles obtained for scenario 18 and residential application.

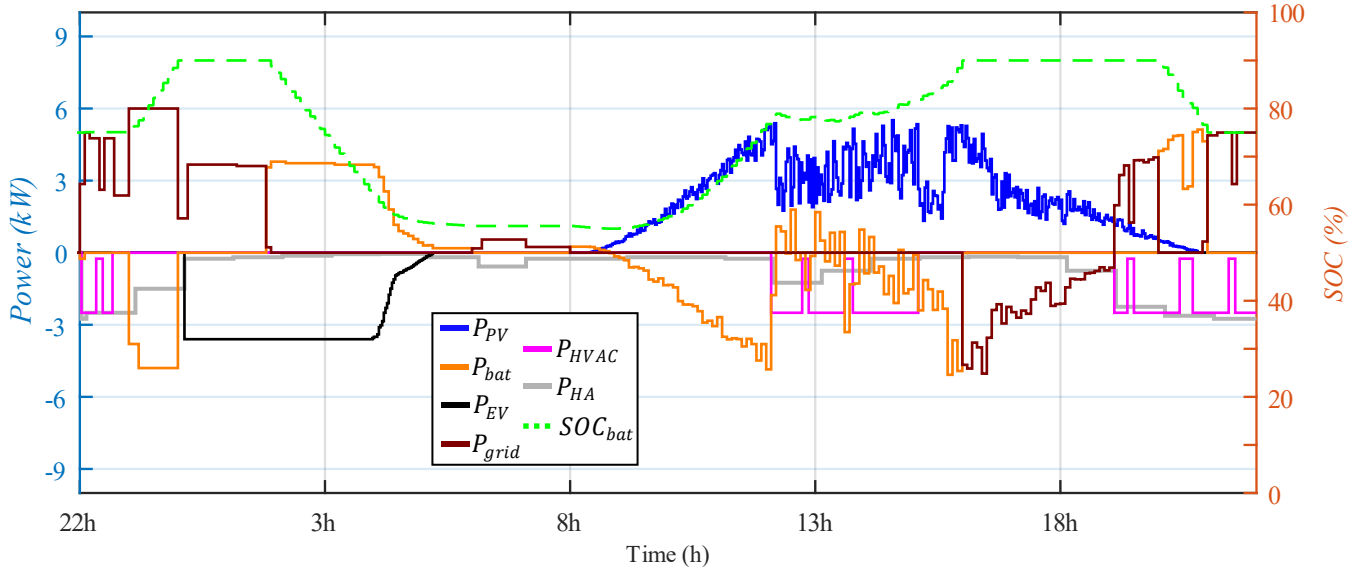

Fig. 1. 38. Power and SOC profiles obtained for scenario 18 and residential application.

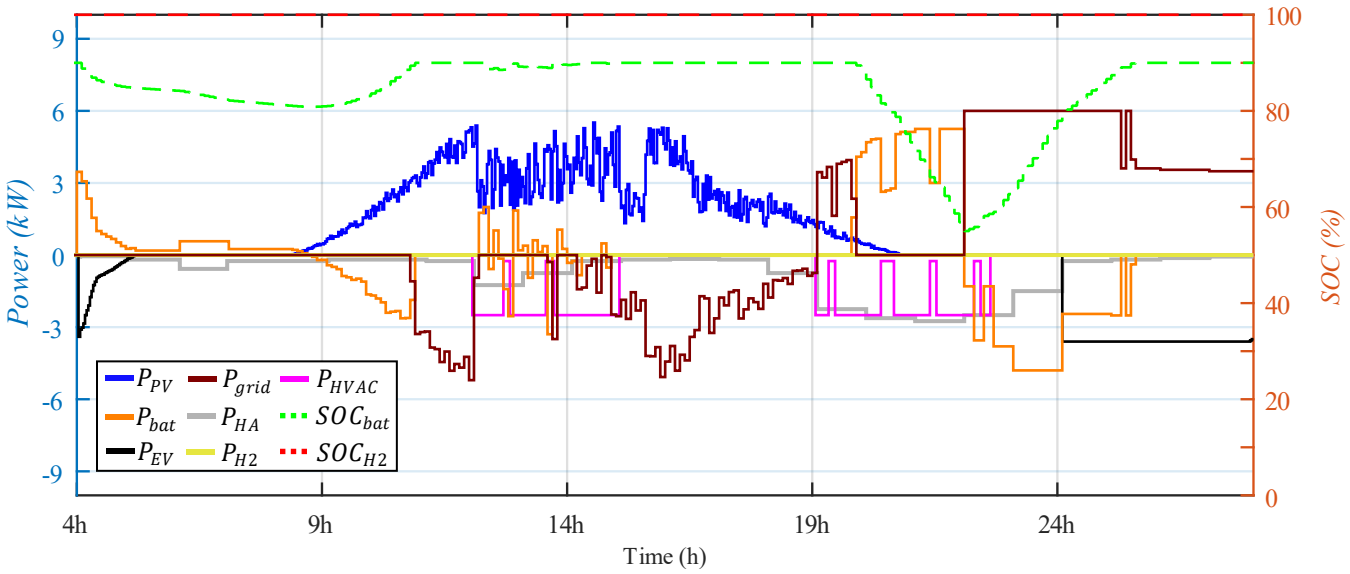

Fig. 1. 39. Power and SOC profiles obtained for scenario 19 and residential application.

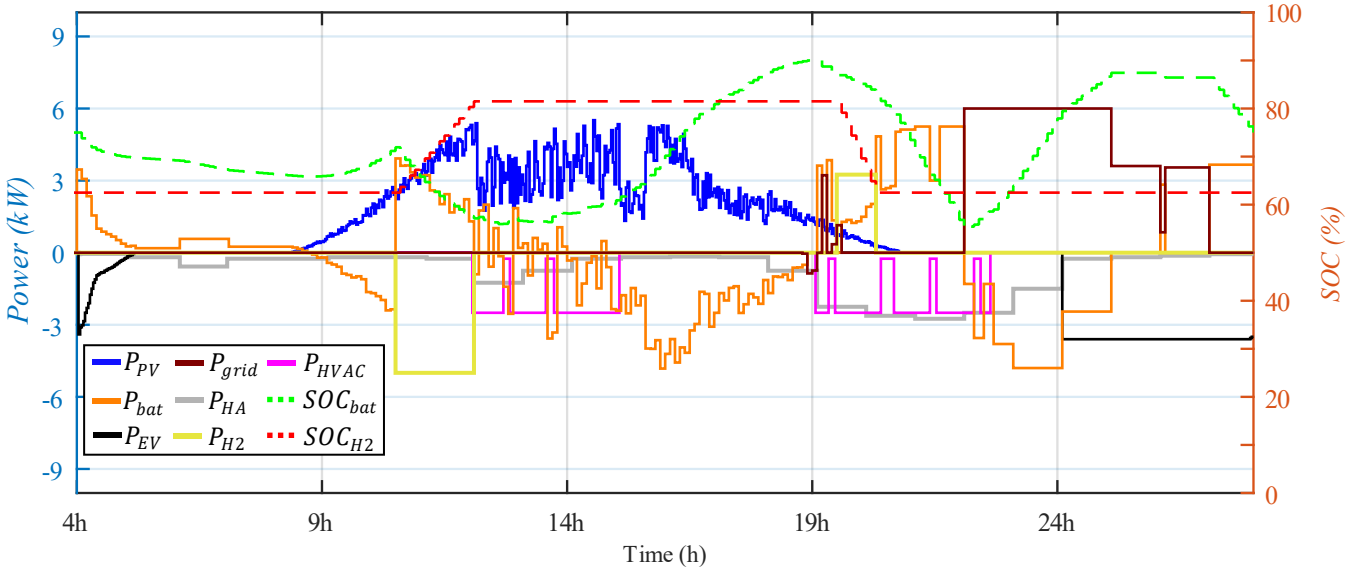

Fig. 1. 40. Power and SOC profiles obtained for scenario 20 and residential application.

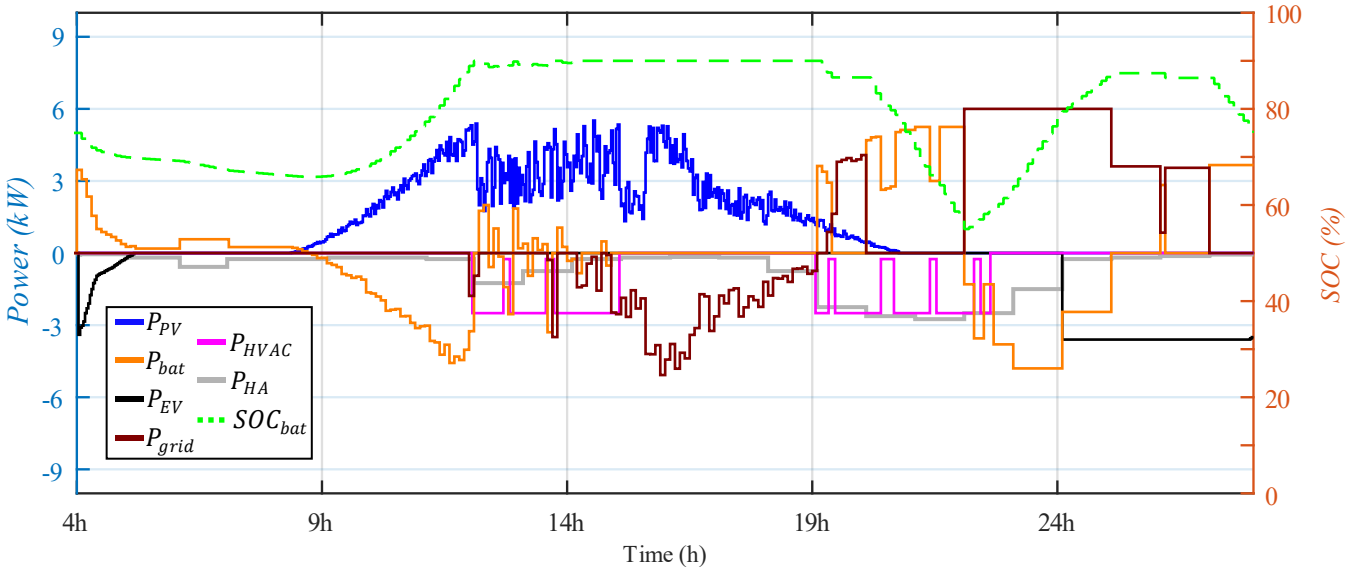

Fig. 1. 41. Power and SOC profiles obtained for scenario 20 and residential application.

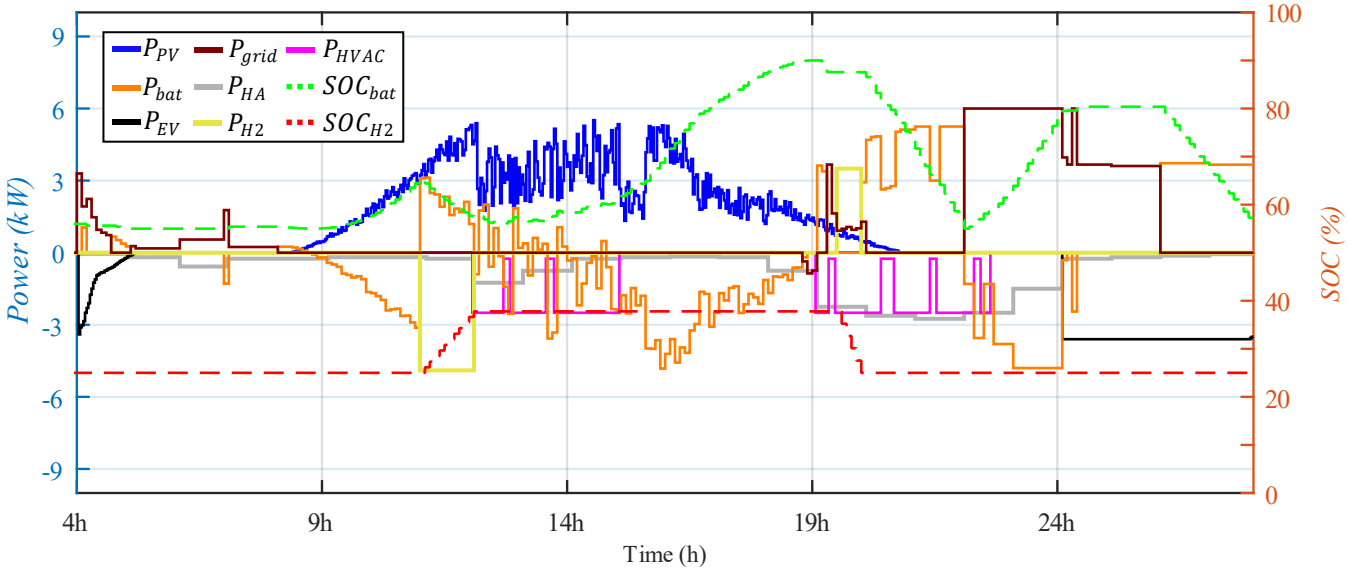

Fig. 1. 42. Power and SOC profiles obtained for scenario 21 and residential application.

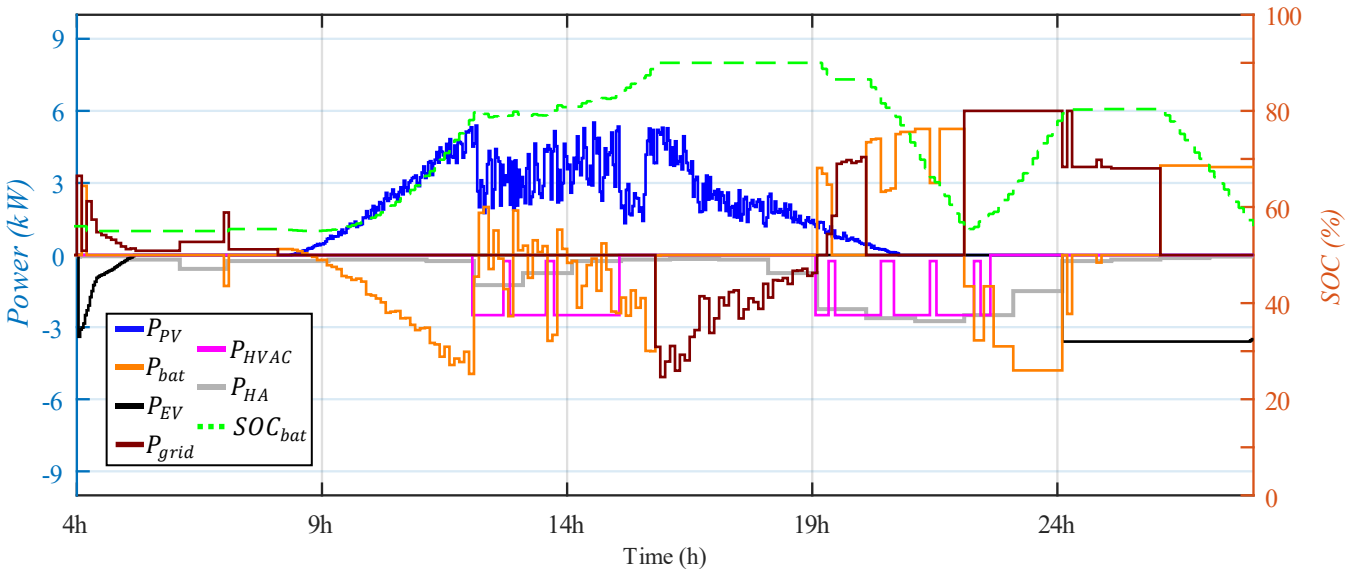

Fig. 1. 43. Power and SOC profiles obtained for scenario 21 and residential application.

Table 1. Results obtained in the microgrid architecture for residential application (case 1, Fig. 1). $PH = 24\ h.\ T_s = 0.1\ h.(360\ sec.)$.

Scenario			Cost							Computational Cost[2] (sec.)
Number	Day	Initial conditions	$Cost_{MPC}$ (€)	$Cost_{MPC}/Cost_{MEG}$ (%)	$Cost_{MPC}^{BSS}$ (€)	$Cost_{MPC}^{BSS}/Cost_{MEG}$ (%)	$Cost_{ren}$ (€)	$Cost_{ren}/Cost_{MEG}$ (%)	$Cost_{MEG}$ (€)	
1	Sunny	Starts at 8h $SOC_{bat}^{ini} = 56\%$ $SOC_{H2}^{ini} = 25\%$ $V_{BUS}^{ini} = 375V$	5.48 Fig. 1. 1	30.67	6.28 Fig. 1. 2	35.14	10.58 Fig. 1. 3	59.21	17.87 Fig. 1. 4	116.19 ($Cost_{MPC}$) 0.99 ($Cost_{MPC}^{BSS}$)
2	Sunny	Starts at 8h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 62.5\%$ $V_{BUS}^{ini} = 375V$	7.54 Fig. 1. 5	42.19	7.98 Fig. 1. 6	44.66	10.58 Fig. 1. 3	59.21	17.87 Fig. 1. 4	11.03 ($Cost_{MPC}$) 1.06 ($Cost_{MPC}^{BSS}$)
3	Sunny	Starts at 22h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$ $V_{BUS}^{ini} = 375V$	6.68 Fig. 1. 7	37.38	7.32 Fig. 1. 8	40.96	10.58	59.21	17.87	8.29 ($Cost_{MPC}$) 1.08 ($Cost_{MPC}^{BSS}$)
4	Sunny	Starts at 22h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 62.5\%$ $V_{BUS}^{ini} = 375V$	5.52 Fig. 1. 9	30.89	6.67 Fig. 1. 10	37.33	10.58	59.21	17.87	33.34 ($Cost_{MPC}$) 1.024 ($Cost_{MPC}^{BSS}$)
5	Sunny	Starts at 4h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$ $V_{BUS}{}_{bat}^{ini} = 375V$	8.42 Fig. 1. 11	47.12	8.42 Fig. 1. 11	47.12	10.58	59.21	17.87	1.80 ($Cost_{MPC}$) 1.11 ($Cost_{MPC}^{BSS}$)
6	Sunny	Starts at 4h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 62.5\%$ $V_{BUS}^{ini} = 375V$	6.64 Fig. 1. 12	37.16	7.06 Fig. 1. 13	39.51	10.58	59.21	17.87	24.49 ($Cost_{MPC}$) 1.04 ($Cost_{MPC}^{BSS}$)
7	Sunny	Starts at 4h $SOC_{bat}^{ini} = 56\%$ $SOC_{H2}^{ini} = 25\%$ $V_{BUS}^{ini} = 375V$	5.36 Fig. 1. 14	29.99	6.09 Fig. 1. 15	34.08	10.58	59.21	17.87	100.54 ($Cost_{MPC}$) 0.98 ($Cost_{MPC}^{BSS}$)
8	Sunny with clouds	Starts at 8h $SOC_{bat}^{ini} = 56\%$ $SOC_{H2}^{ini} = 25\%$ $V_{BUS}^{ini} = 375V$	5.96 Fig. 1. 16	33.35	6.65 Fig. 1. 17	37.21	10.96 Fig. 1. 18	61.33	17.87 Fig. 1. 4	9.46 ($Cost_{MPC}$) 0.97 ($Cost_{MPC}^{BSS}$)

[2] CPU processor Intel Core i7, 3.2 GHz with 16 GB RAM.

9	Sunny with clouds	Starts at 8h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 62.5\%$ $V_{BUS}^{ini} = 375V$	7.91 Fig. 1. 19	44.26	8.34 Fig. 1. 20	46.67	10.96 Fig. 1. 18	61.33	17.87 Fig. 1. 4	30.13 ($Cost_{MPC}$) 1.44 ($Cost_{MPC}^{BSS}$)
10	Sunny with clouds	Starts at 22h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$ $V_{BUS}^{ini} = 375V$	7.14 Fig. 1. 21	39.96	7.69 Fig. 1. 22	43.03	10.96	61.33	17.87	8.40 ($Cost_{MPC}$) 1.18 ($Cost_{MPC}^{BSS}$)
11	Sunny with clouds	Starts at 22h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 62.5\%$ $V_{BUS}^{ini} = 375V$	6.02 Fig. 1. 23	33.69	7.05 Fig. 1. 24	39.45	10.96	61.33	17.87	20.53 ($Cost_{MPC}$) 1.03 ($Cost_{MPC}^{BSS}$)
12	Sunny with clouds	Starts at 4h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$ $V_{BUS}^{ini} = 375V$	8.73 Fig. 1. 25	48.85	8.73 Fig. 1. 25	48.85	10.96	61.33	17.87	1.70 ($Cost_{MPC}$) 1.26 ($Cost_{MPC}^{BSS}$)
13	Sunny with clouds	Starts at 4h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 62.5\%$ $V_{BUS}^{ini} = 375V$	6.95 Fig. 1. 26	38.89	7.37 Fig. 1. 27	41.24	10.96	61.33	17.87	15.49 ($Cost_{MPC}$) 1.22 ($Cost_{MPC}^{BSS}$)
14	Sunny with clouds	Starts at 4h $SOC_{bat}^{ini} = 56\%$ $SOC_{H2}^{ini} = 25\%$ $V_{BUS}^{ini} = 375V$	5.72 Fig. 1. 28	32.01	6.40 Fig. 1. 29	35.81	10.96	61.33	17.87	7.26 ($Cost_{MPC}$) 0.97 ($Cost_{MPC}^{BSS}$)
15	Cloudy	Starts at 8h $SOC_{bat}^{ini} = 56\%$ $SOC_{H2}^{ini} = 25\%$ $V_{BUS}^{ini} = 375V$	8.40 Fig. 1. 30	47.01	8.48 Fig. 1. 31	47.45	13.08 Fig. 1. 32	73.20	17.87 Fig. 1.4	14.66 ($Cost_{MPC}$) 0.98 ($Cost_{MPC}^{BSS}$)
16	Cloudy	Starts at 8h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 62.5\%$ $V_{BUS}^{ini} = 375V$	9.93 Fig. 1. 33	55.57	10.17 Fig. 1. 34	56.91	13.08 Fig. 1. 32	73.20	17.87 Fig. 1.4	9.09 ($Cost_{MPC}$) 1.09 ($Cost_{MPC}^{BSS}$)
17	Cloudy	Starts at 22h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$ $V_{BUS}^{ini} = 375V$	9.52 Fig. 1. 35	53.27	9.55 Fig. 1. 36	53.44	13.08	73.20	17.87	14.75 ($Cost_{MPC}$) 1.30 ($Cost_{MPC}^{BSS}$)
18	Cloudy	Starts at 22h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 62.5\%$ $V_{BUS}^{ini} = 375V$	8.73 Fig. 1. 37	48.85	8.90 Fig. 1. 38	49.80	13.08	73.20	17.87	6.56 ($Cost_{MPC}$) 1.18 ($Cost_{MPC}^{BSS}$)

19	Cloudy	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 90\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 100\%$ $\mathrm{V}_{\mathrm{BUS}}^{\mathrm{ini}} = 375\mathrm{V}$	10.60 Fig. 1. 39	59.32	10.60 Fig. 1. 39	59.32	13.08	73.20	17.87	1.69 ($\mathrm{Cost}_{\mathrm{MPC}}$) 1.11 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
20	Cloudy	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 62.5\%$ $\mathrm{V}_{\mathrm{BUS}}^{\mathrm{ini}} = 375\mathrm{V}$	9.04 Fig. 1. 40	50.59	9.23 Fig. 1. 41	51.65	13.08	73.20	17.87	14.11 ($\mathrm{Cost}_{\mathrm{MPC}}$) 1.21 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
21	Cloudy	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 56\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 25\%$ $\mathrm{V}_{\mathrm{BUS}}^{\mathrm{ini}} = 375\mathrm{V}$	8.17 Fig. 1. 42	45.72	8.27 Fig. 1. 43	46.28	13.08	73.20	17.87	14.53($\mathrm{Cost}_{\mathrm{MPC}}$) 0.99 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)

2. Microgrid architecture for electric vehicle charging station application (case 2, Fig. 1).

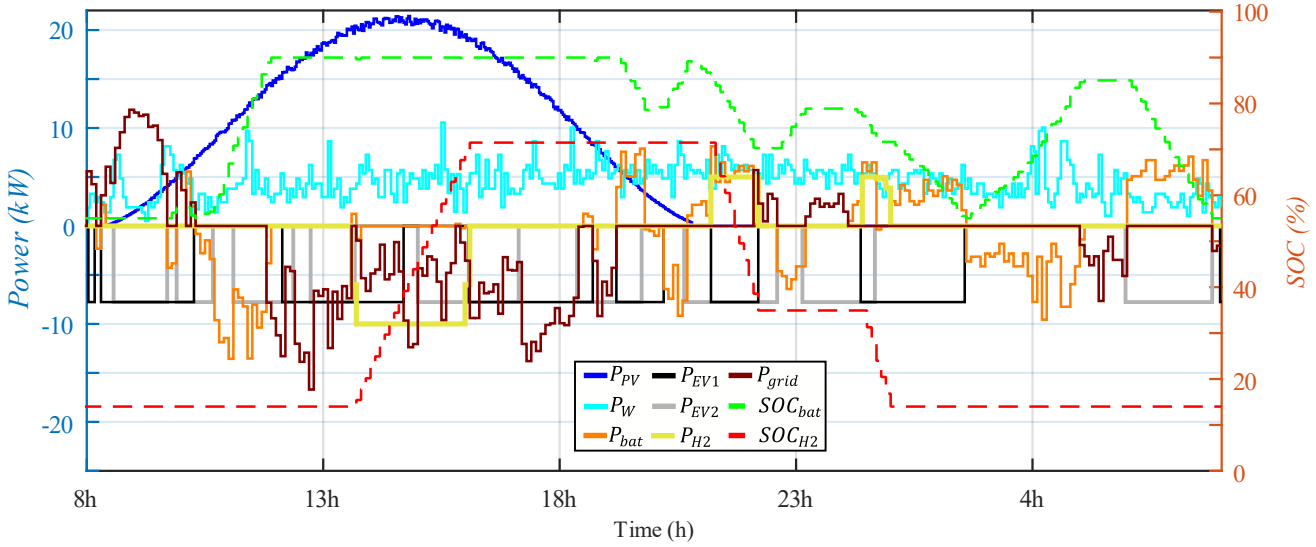

Fig. 2. 1. Power and SOC profiles obtained for scenario 1 and electric vehicle charging station application.

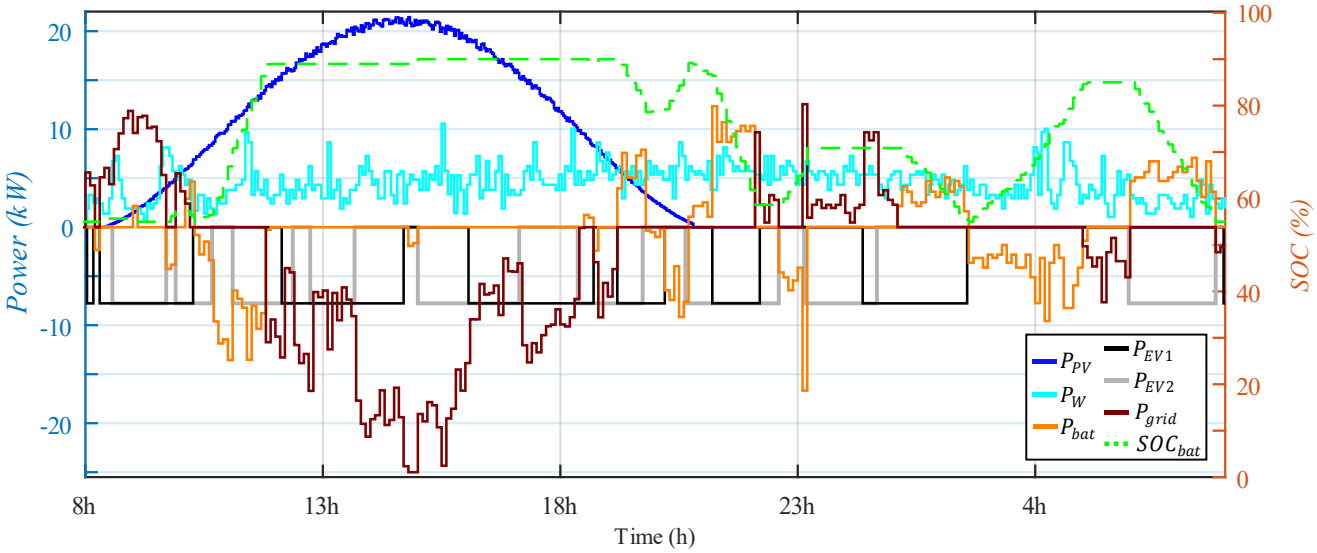

Fig. 2. 2. Power and SOC profiles obtained for scenario 1 and electric vehicle charging station application.

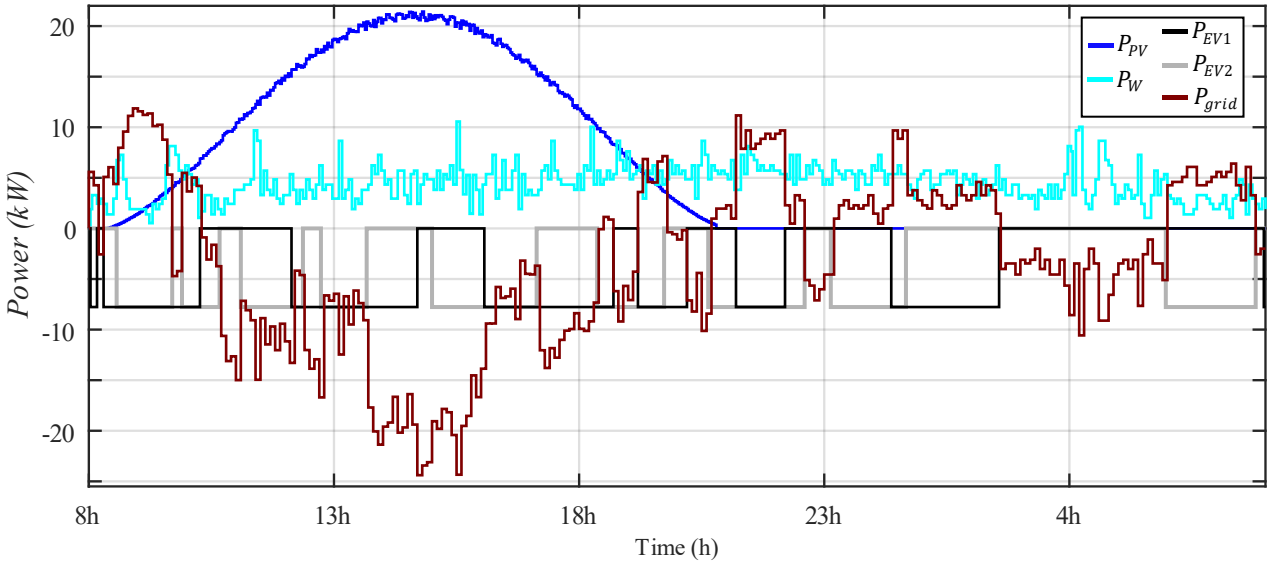

Fig. 2. 3. Power and SOC profiles obtained for scenario 1 and 4 and electric vehicle charging station application.

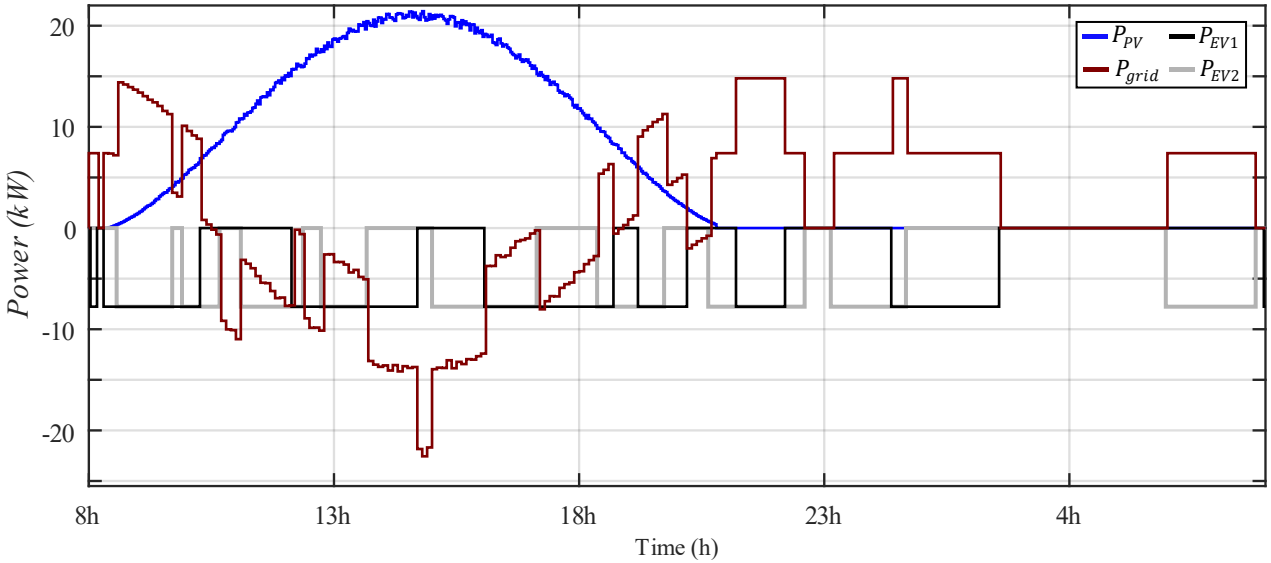

Fig. 2. 4. Power and SOC profiles obtained for scenario 1, 4 and 5 and electric vehicle charging station application.

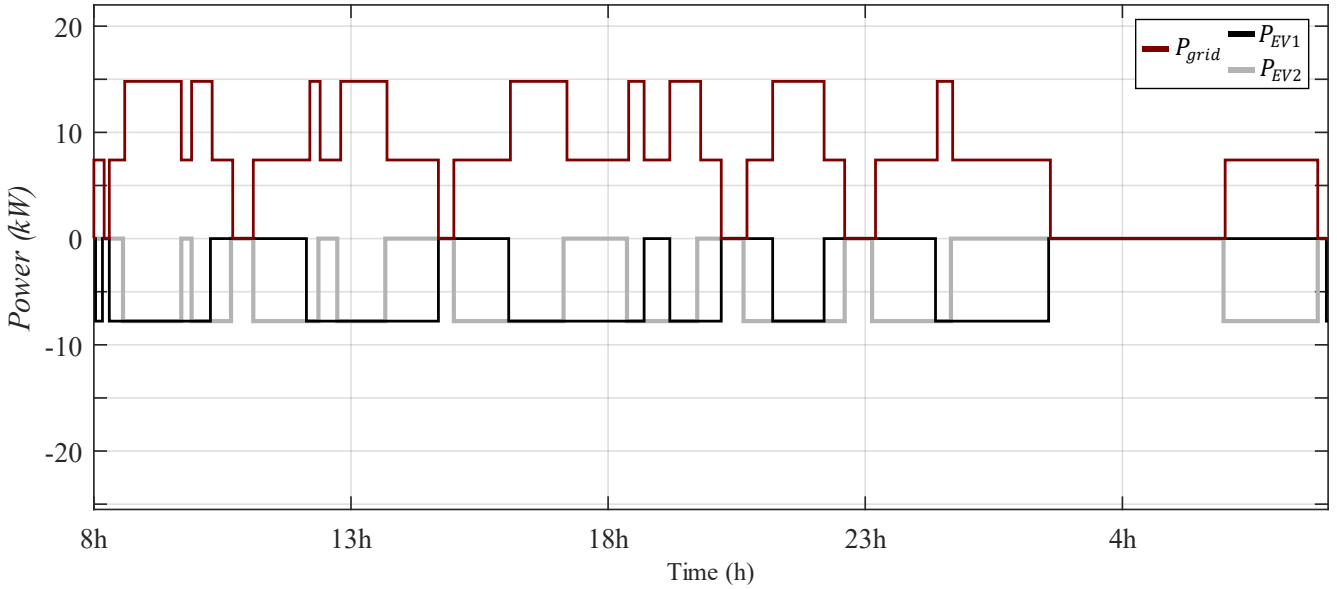

Fig. 2. 5. Power and SOC profiles obtained for scenario 1, 2, 3, 4, 5, 19, 20 and 21 and electric vehicle charging station application.

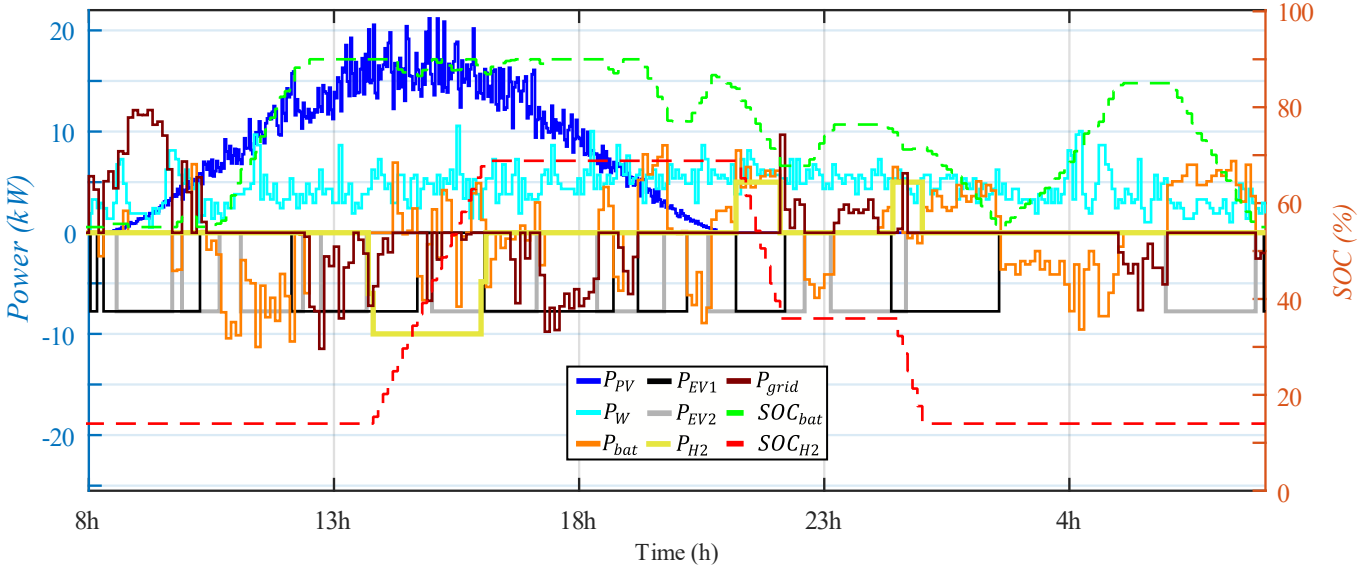

Fig. 2. 6. Power and SOC profiles obtained for scenario 2 and electric vehicle charging station application.

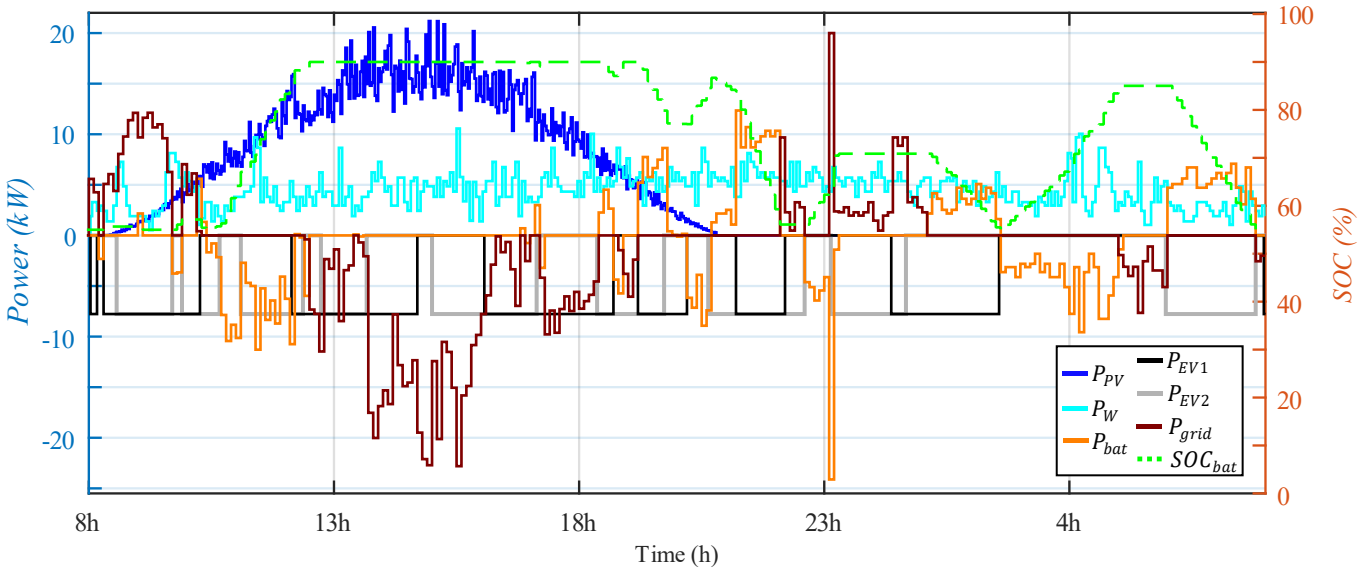

Fig. 2. 7. Power and SOC profiles obtained for scenario 2 and electric vehicle charging station application.

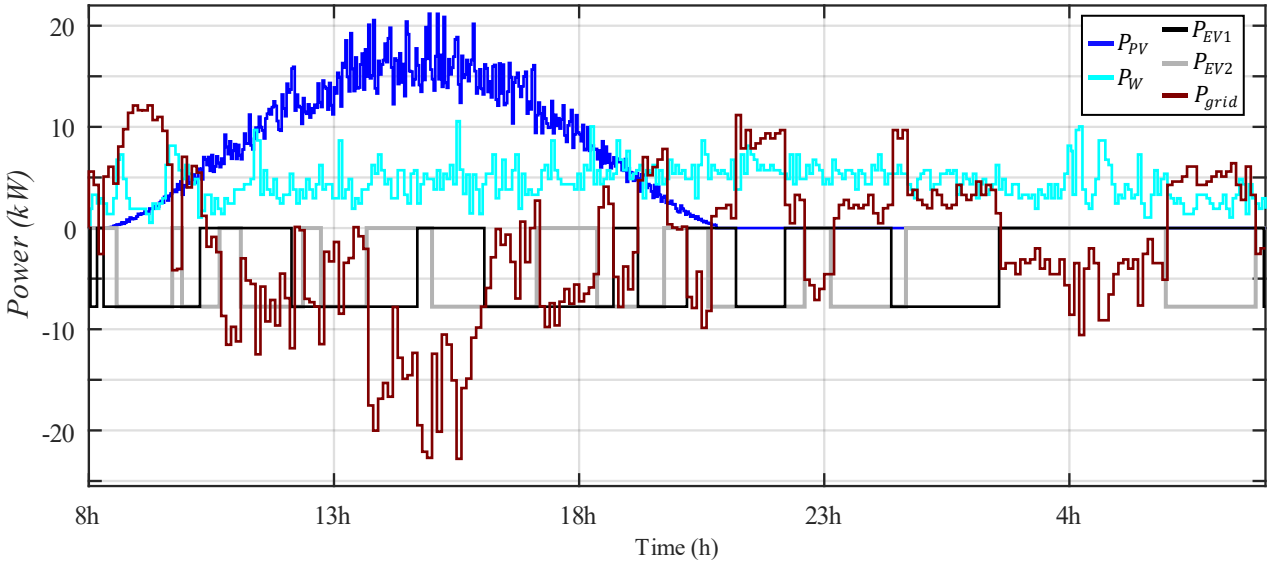

Fig. 2. 8. Power and SOC profiles obtained for scenario 2 and 3 and electric vehicle charging station application.

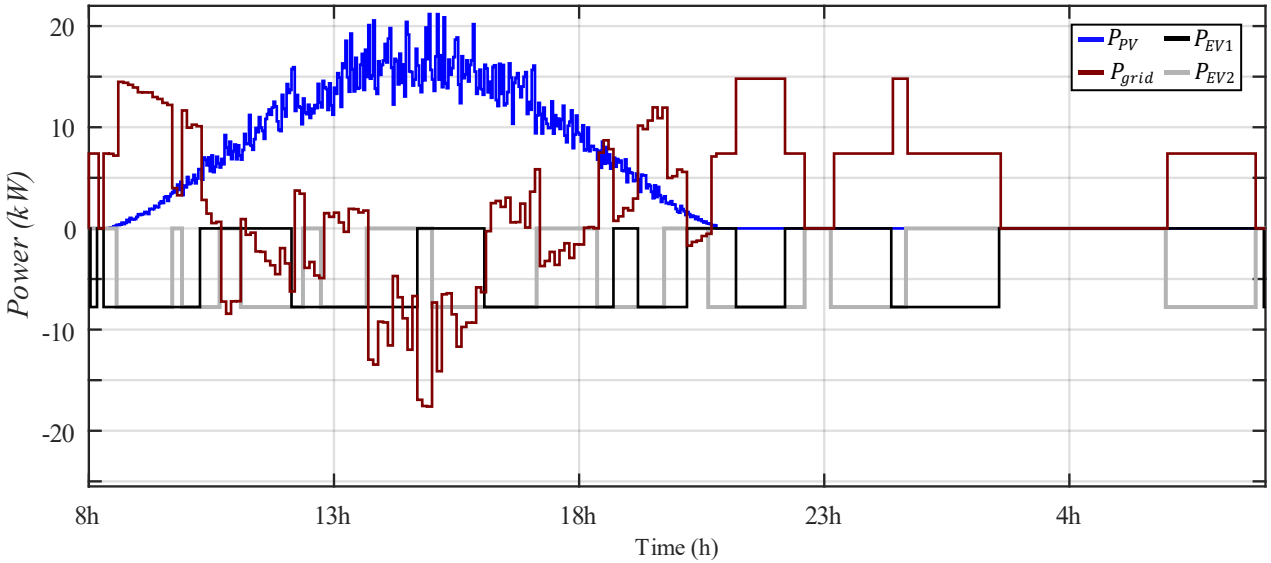

Fig. 2. 9. Power and SOC profiles obtained for scenario 2 and 3 and electric vehicle charging station application.

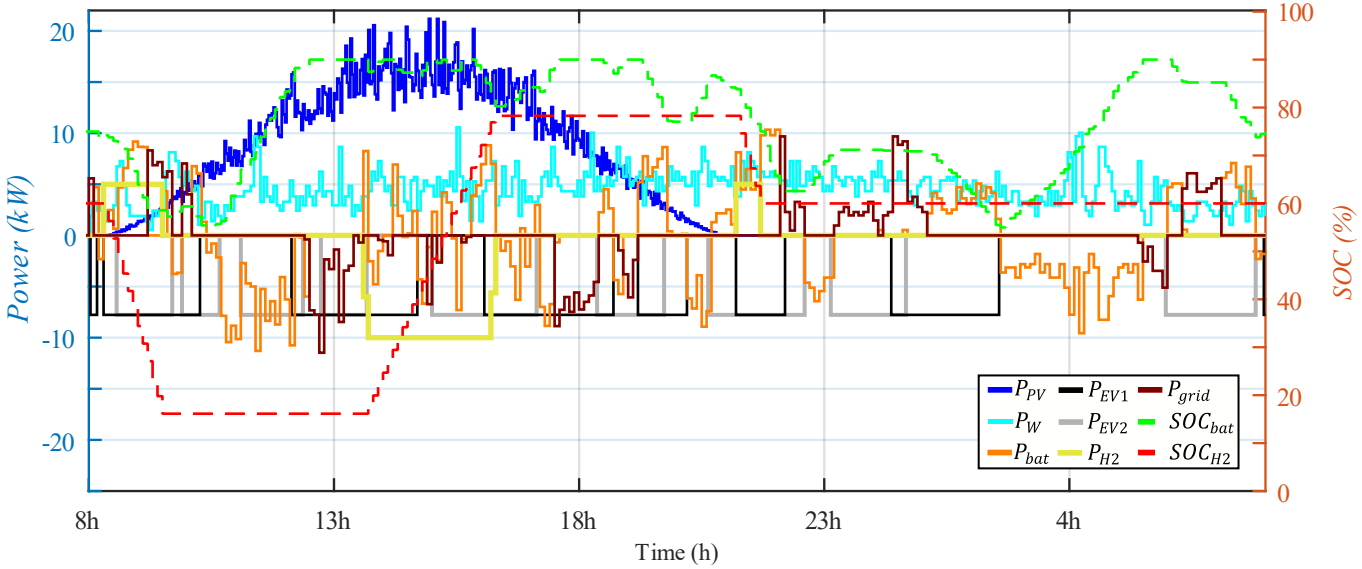

Fig. 2. 10. Power and SOC profiles obtained for scenario 3 and electric vehicle charging station application.

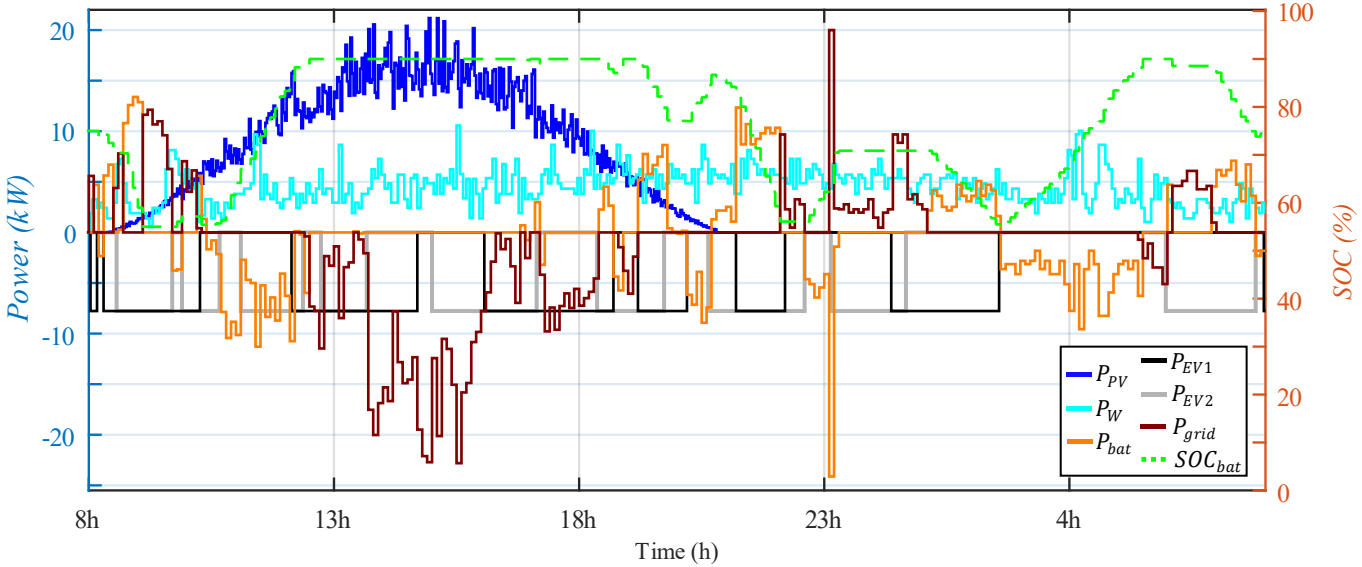

Fig. 2. 11. Power and SOC profiles obtained for scenario 3 and electric vehicle charging station application.

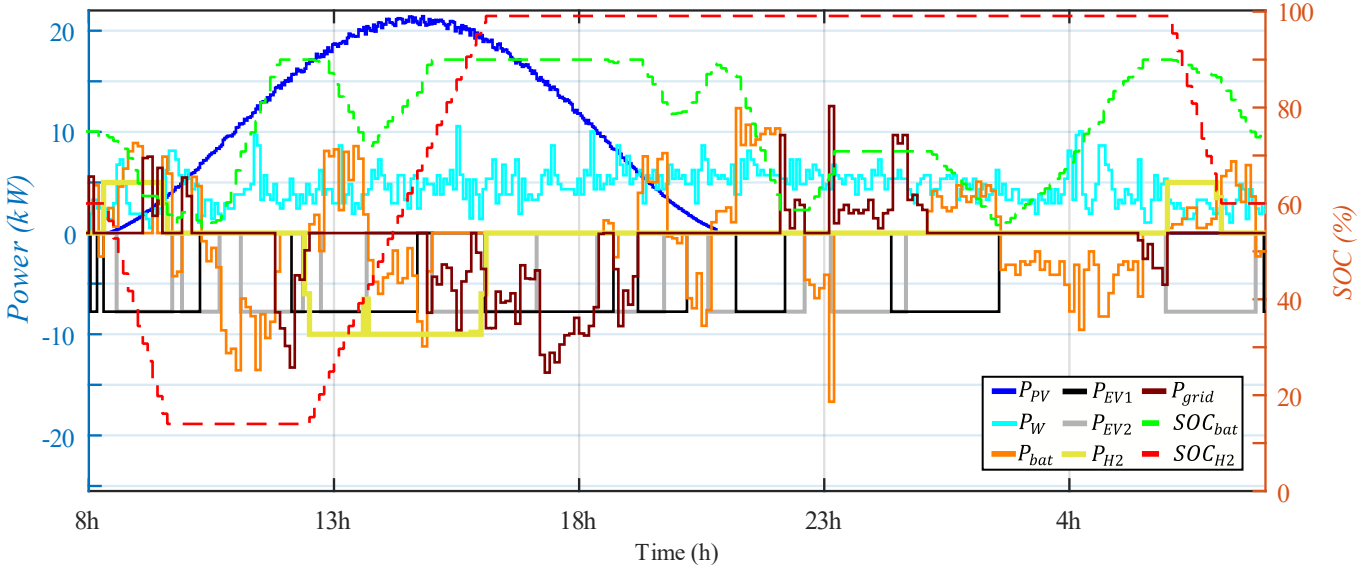

Fig. 2. 12. Power and SOC profiles obtained for scenario 4 and electric vehicle charging station application.

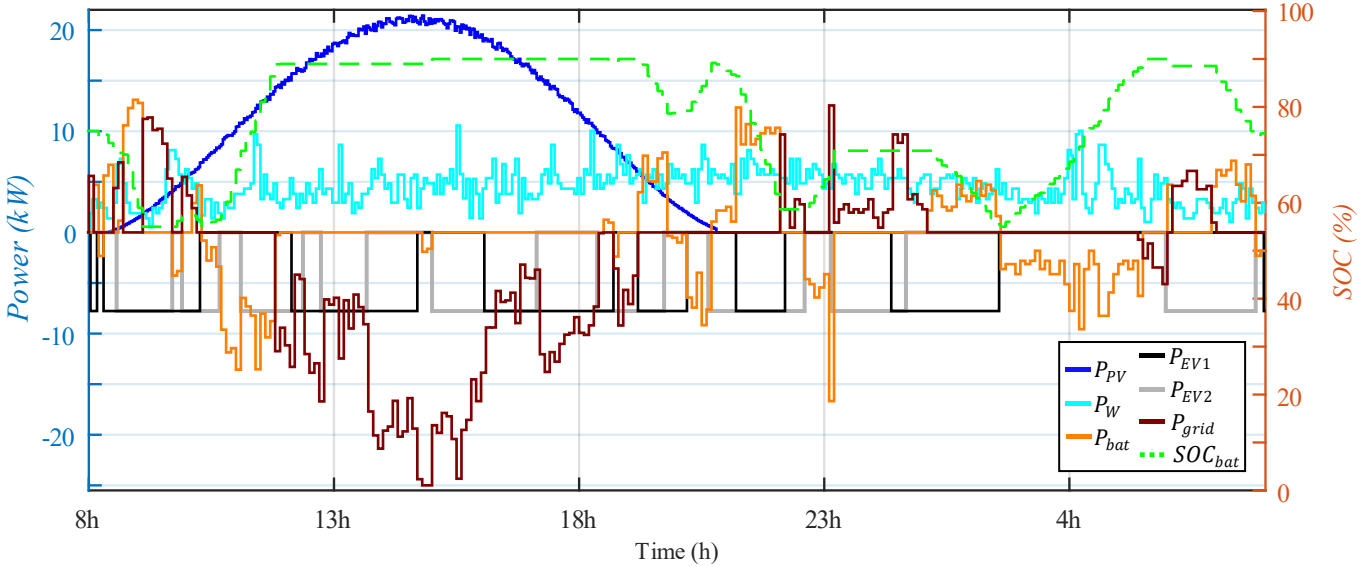

Fig. 2. 13. Power and SOC profiles obtained for scenario 4 and electric vehicle charging station application.

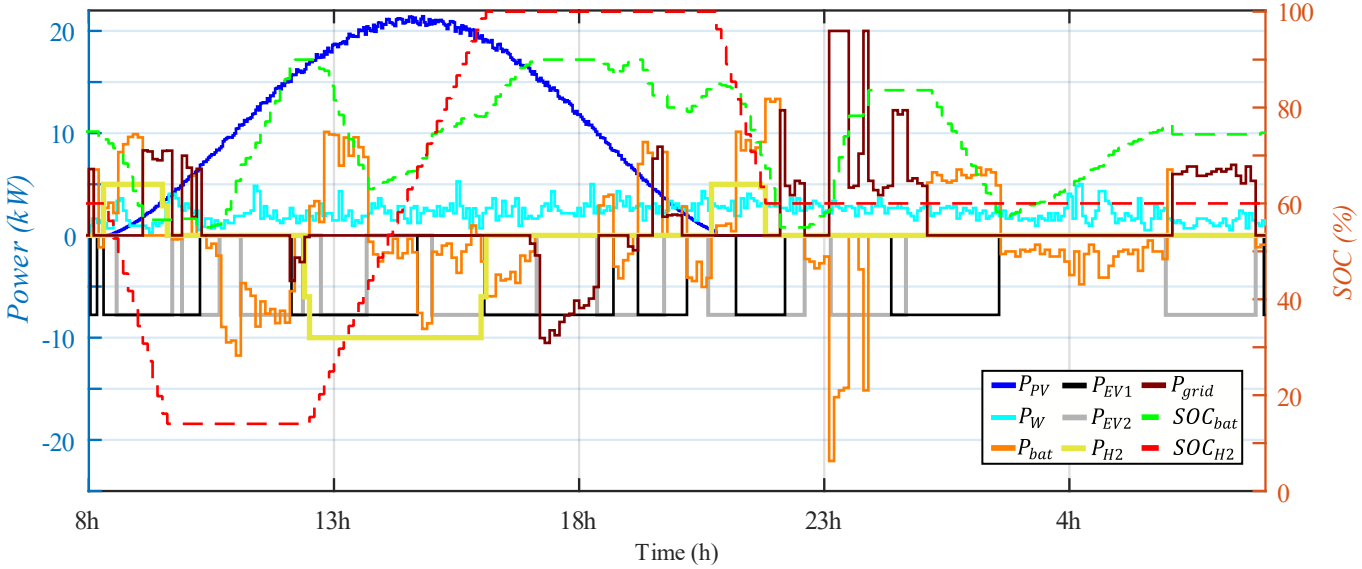

Fig. 2. 14. Power and SOC profiles obtained for scenario 5 and electric vehicle charging station application.

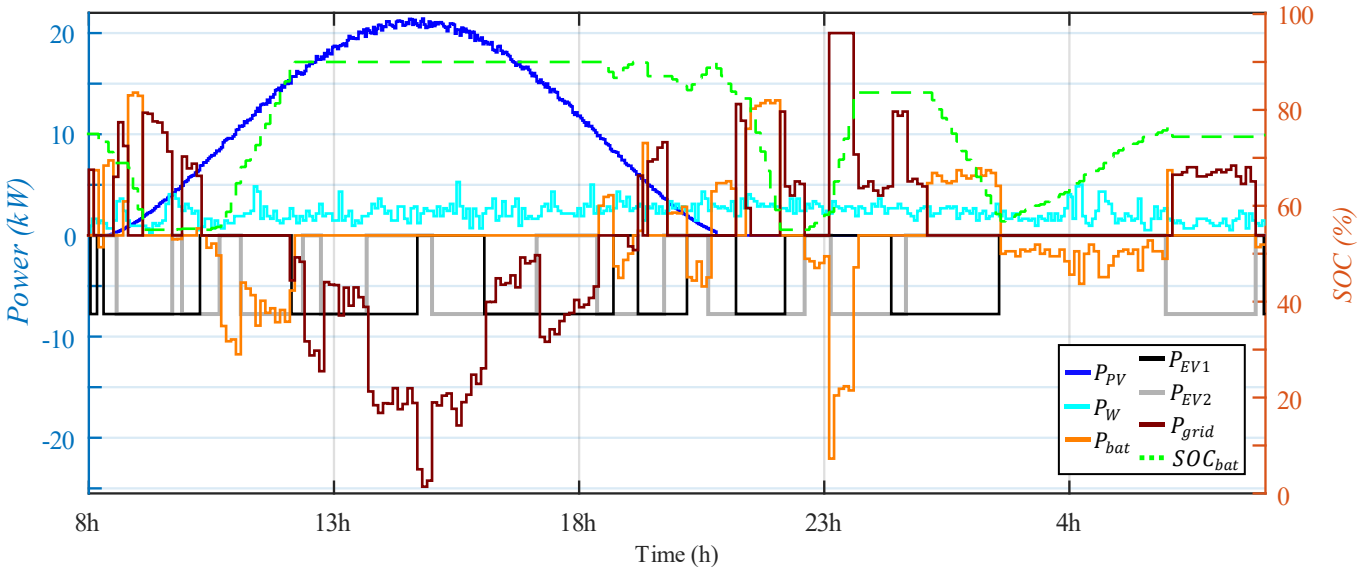

Fig. 2. 15. Power and SOC profiles obtained for scenario 5 and electric vehicle charging station application.

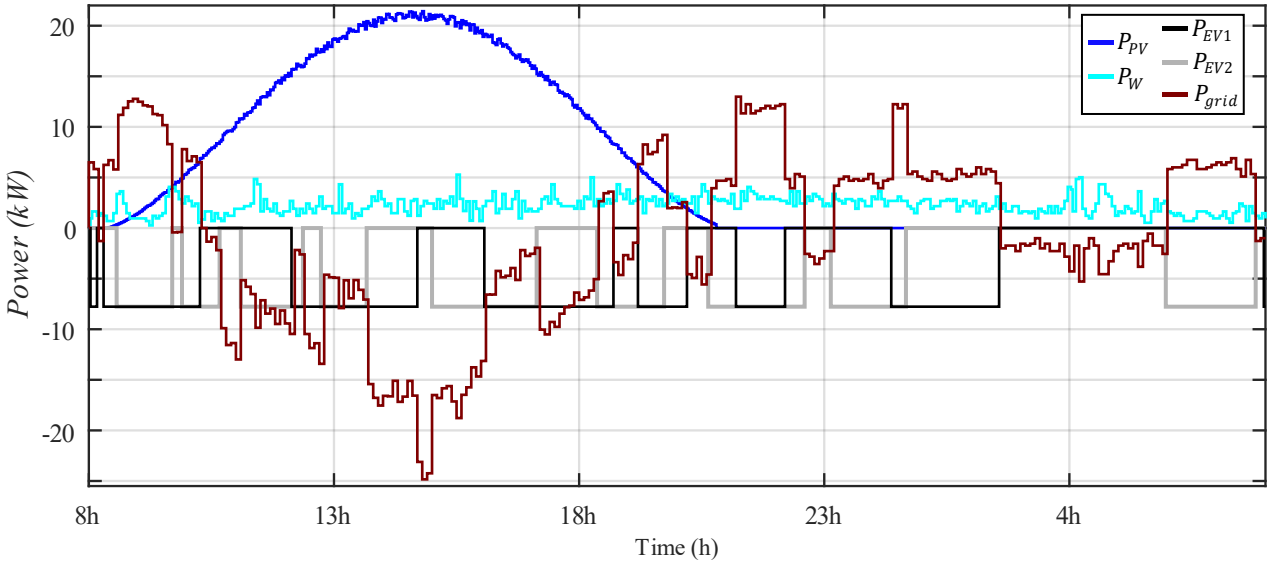

Fig. 2. 16. Power and SOC profiles obtained for scenario 5 and electric vehicle charging station application.

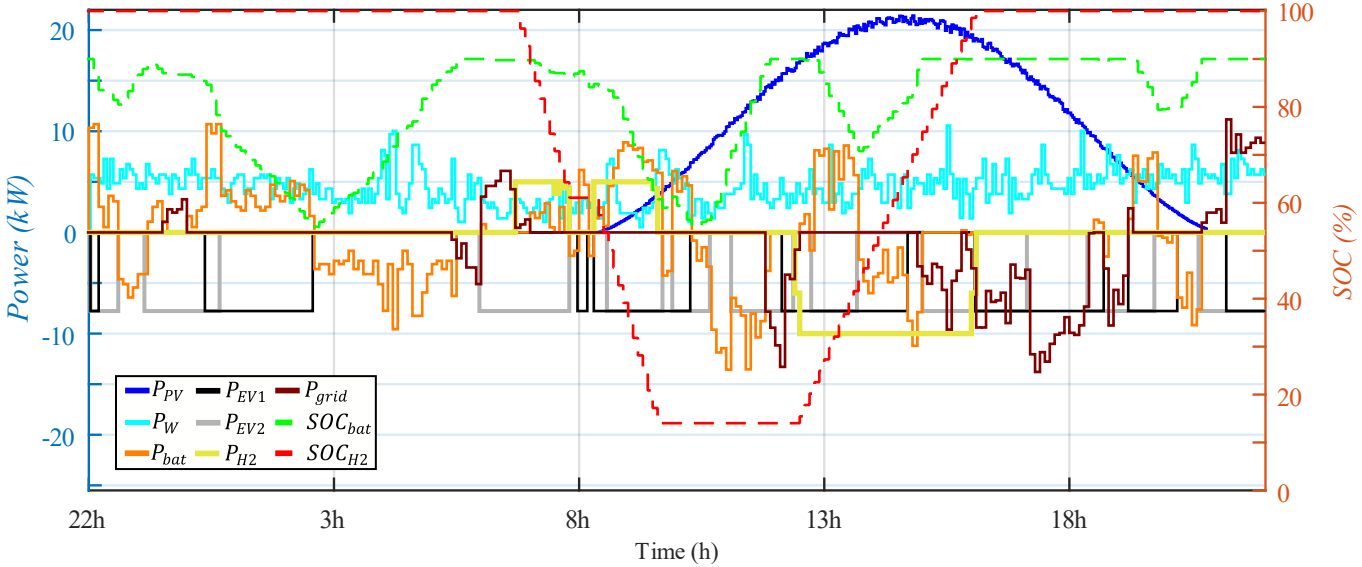

Fig. 2. 17. Power and SOC profiles obtained for scenario 6 and electric vehicle charging station application.

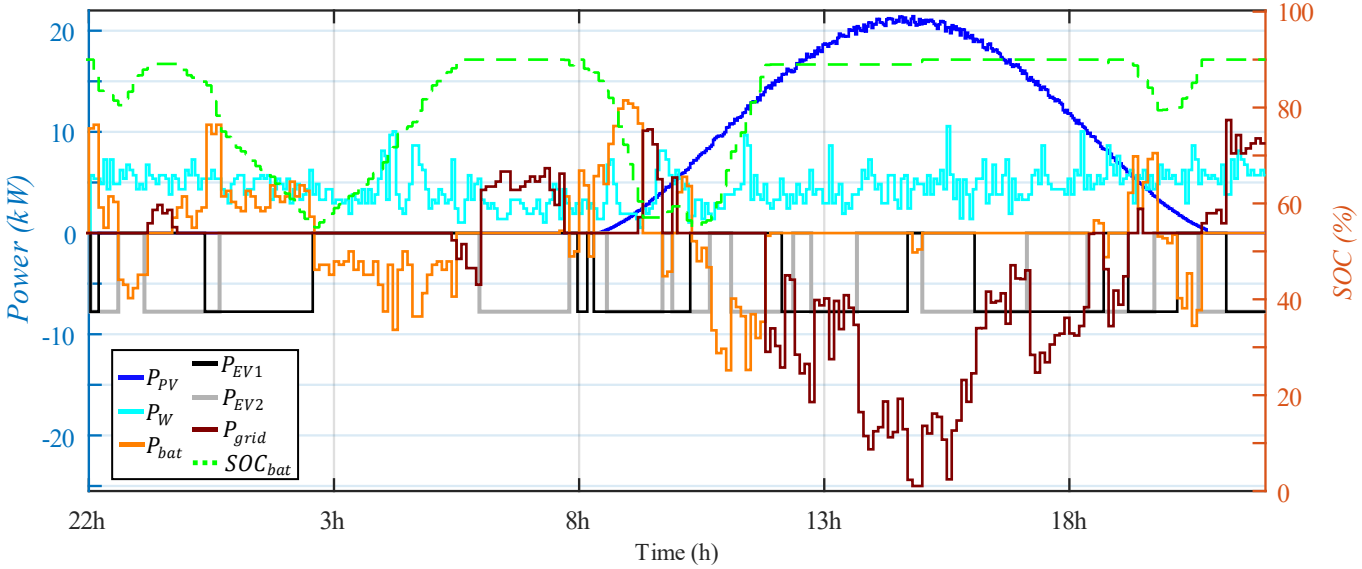

Fig. 2. 18. Power and SOC profiles obtained for scenario 6 and electric vehicle charging station application.

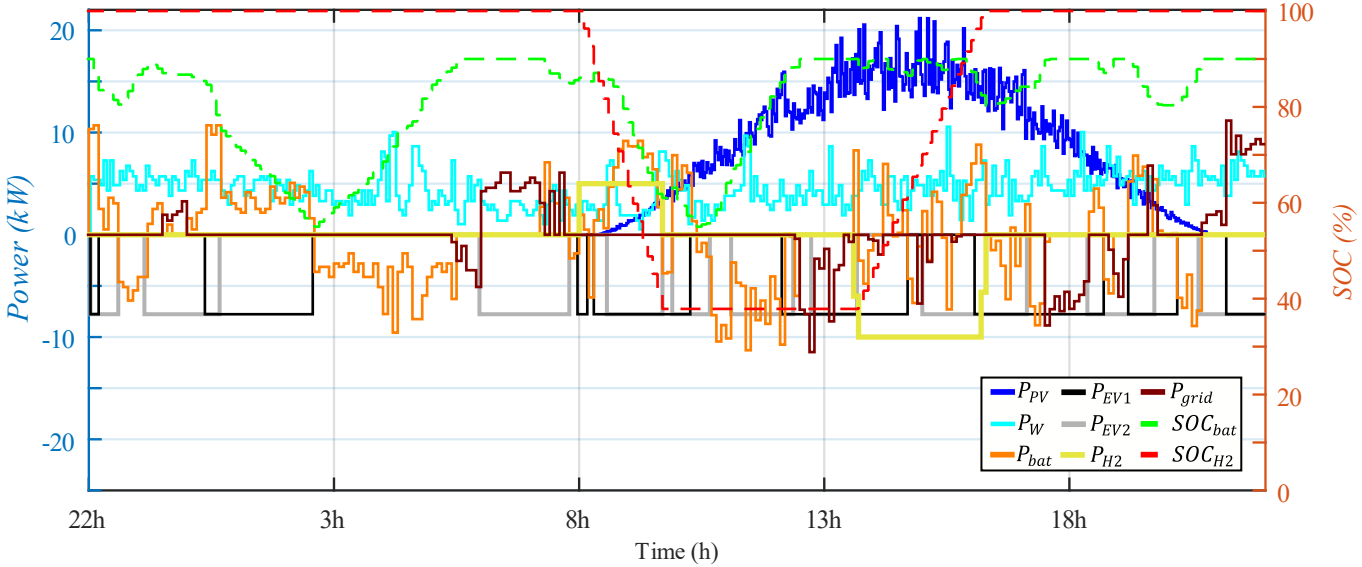

Fig. 2. 19. Power and SOC profiles obtained for scenario 7 and electric vehicle charging station application.

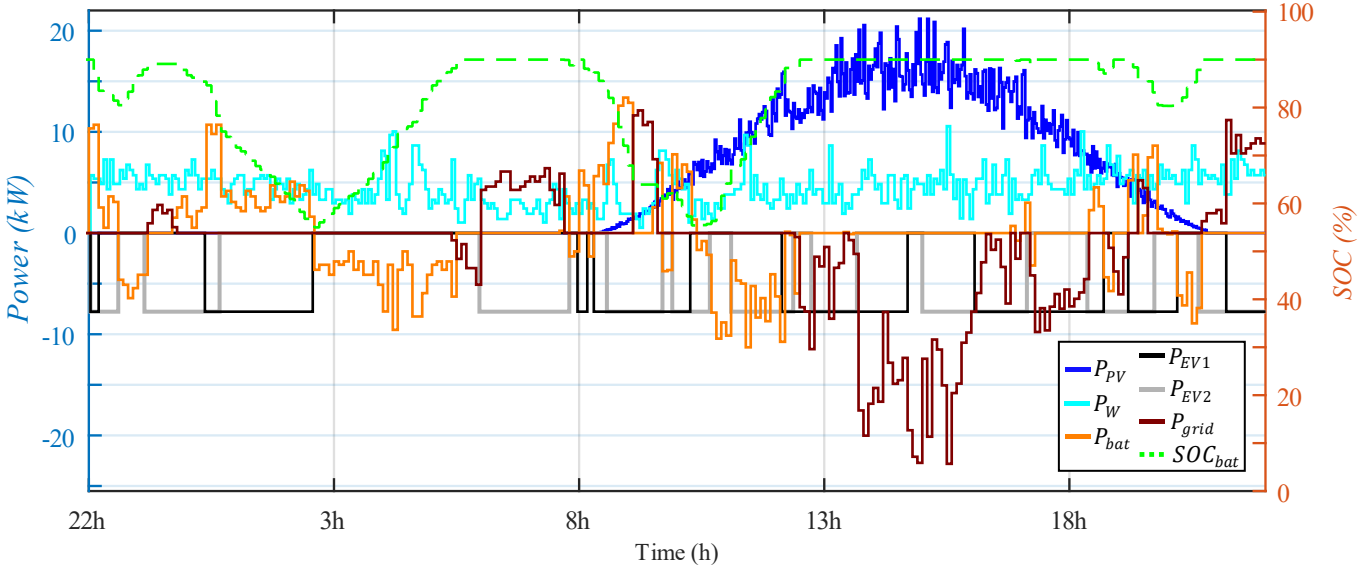

Fig. 2. 20. Power and SOC profiles obtained for scenario 7 and electric vehicle charging station application.

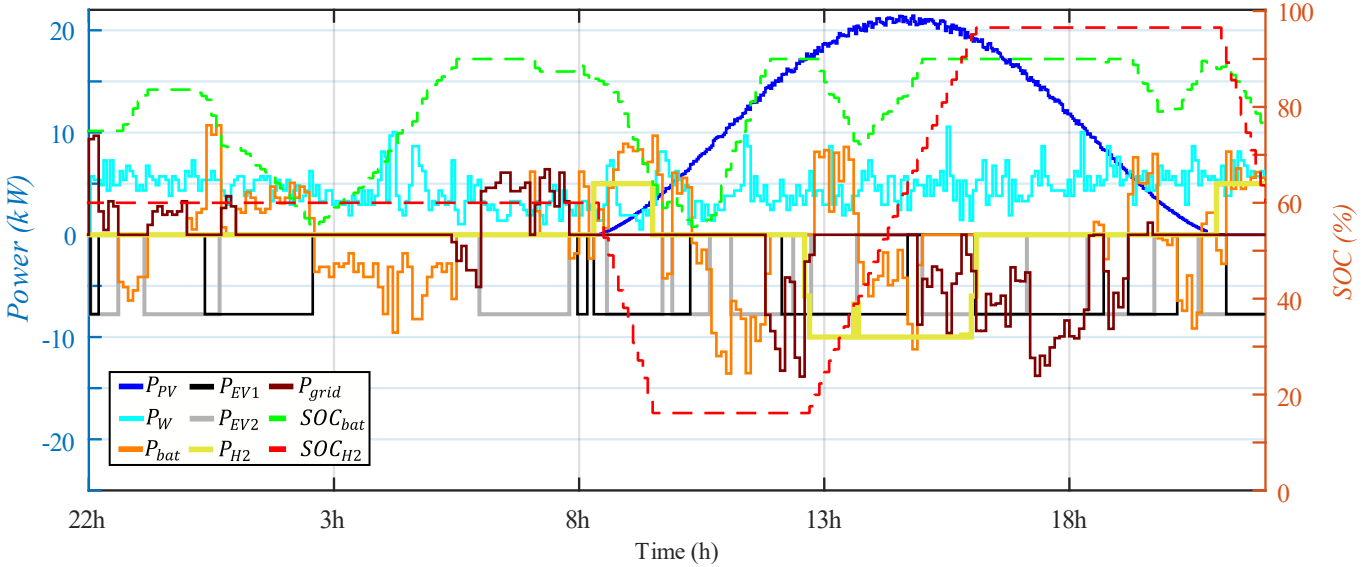

Fig. 2. 21. Power and SOC profiles obtained for scenario 8 and electric vehicle charging station application.

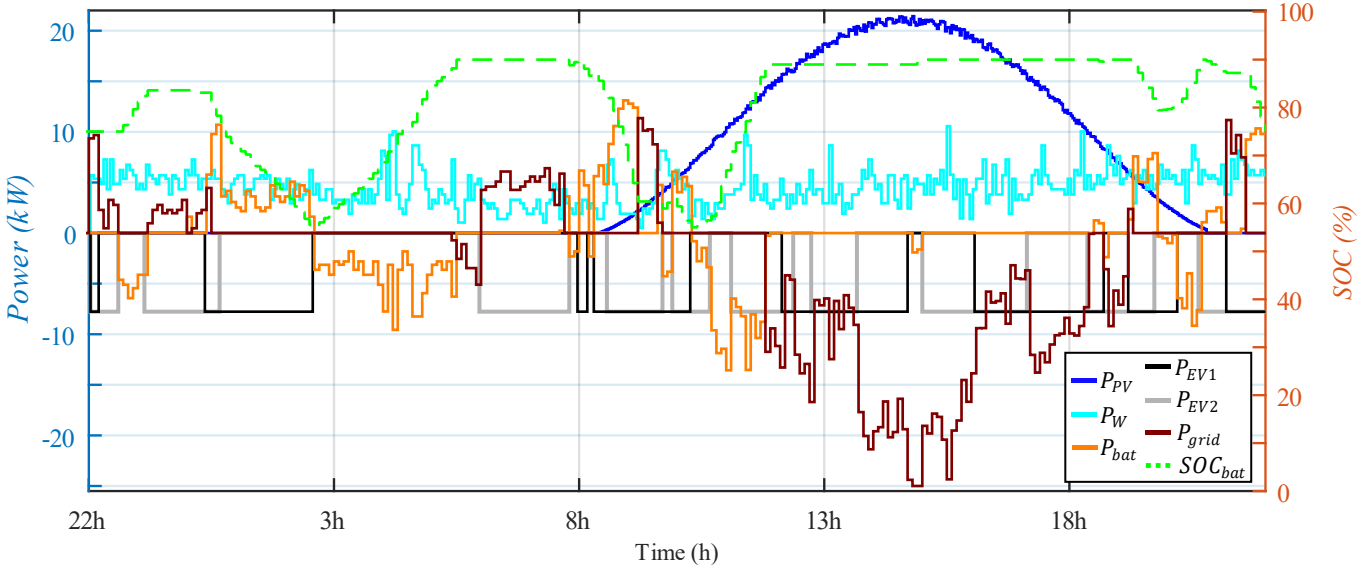

Fig. 2. 22. Power and SOC profiles obtained for scenario 8 and electric vehicle charging station application.

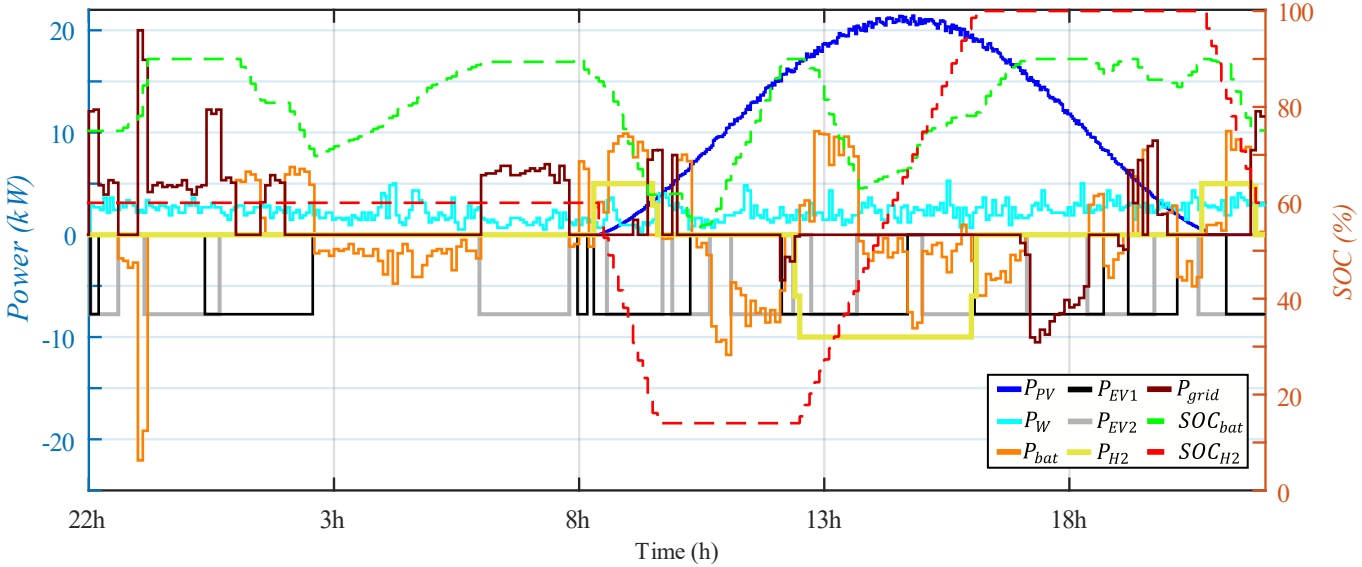

Fig. 2. 23. Power and SOC profiles obtained for scenario 9 and electric vehicle charging station application.

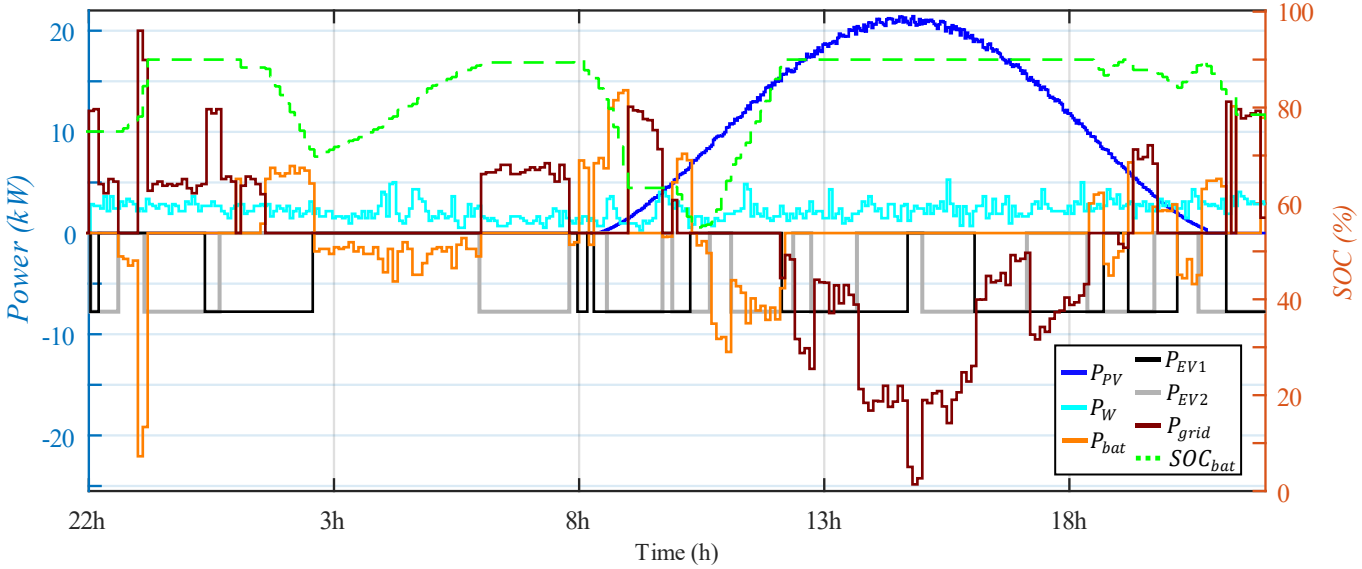

Fig. 2. 24. Power and SOC profiles obtained for scenario 9 and electric vehicle charging station application.

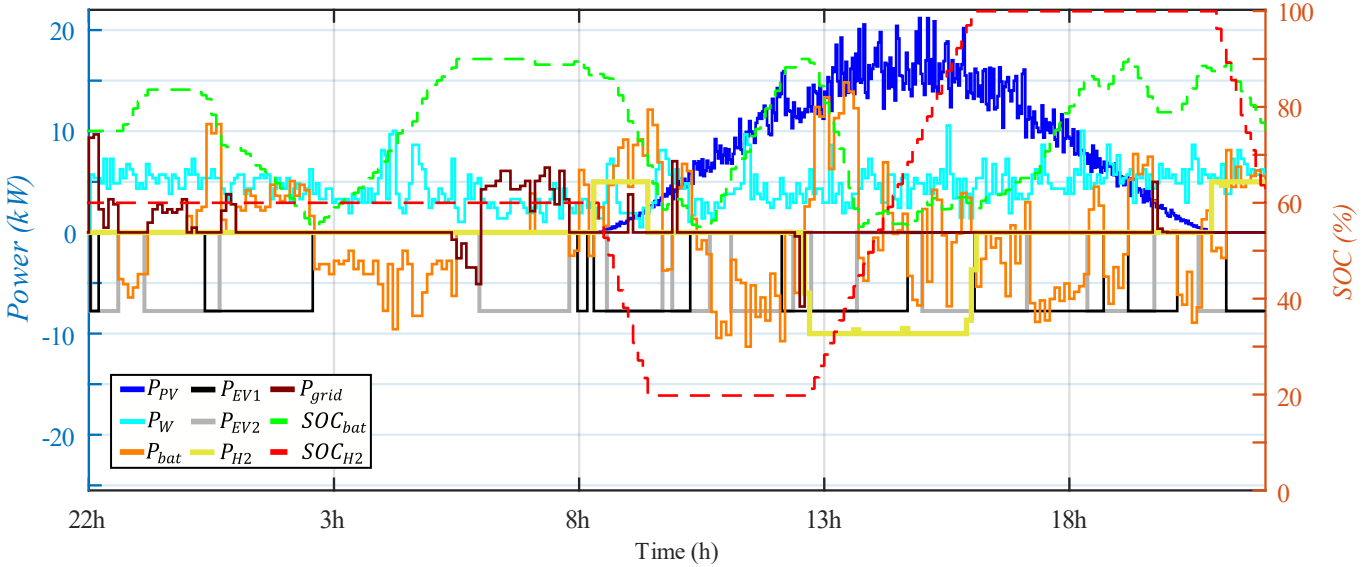

Fig. 2. 25. Power and SOC profiles obtained for scenario 10 and electric vehicle charging station application.

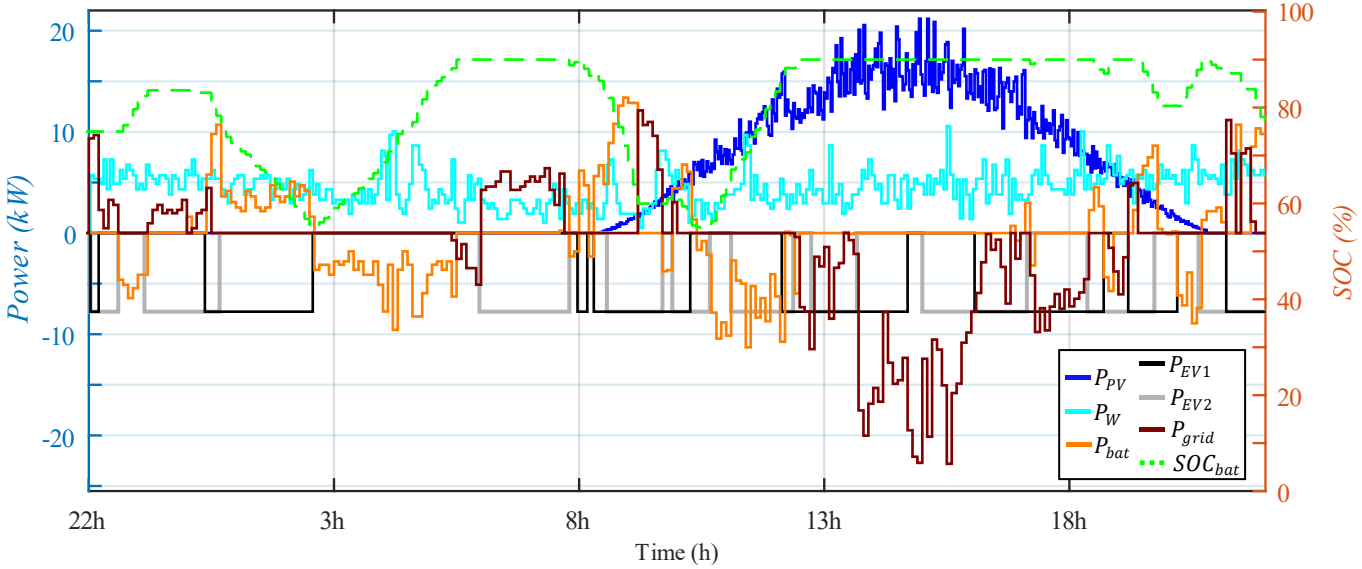

Fig. 2. 26. Power and SOC profiles obtained for scenario 10 and electric vehicle charging station application.

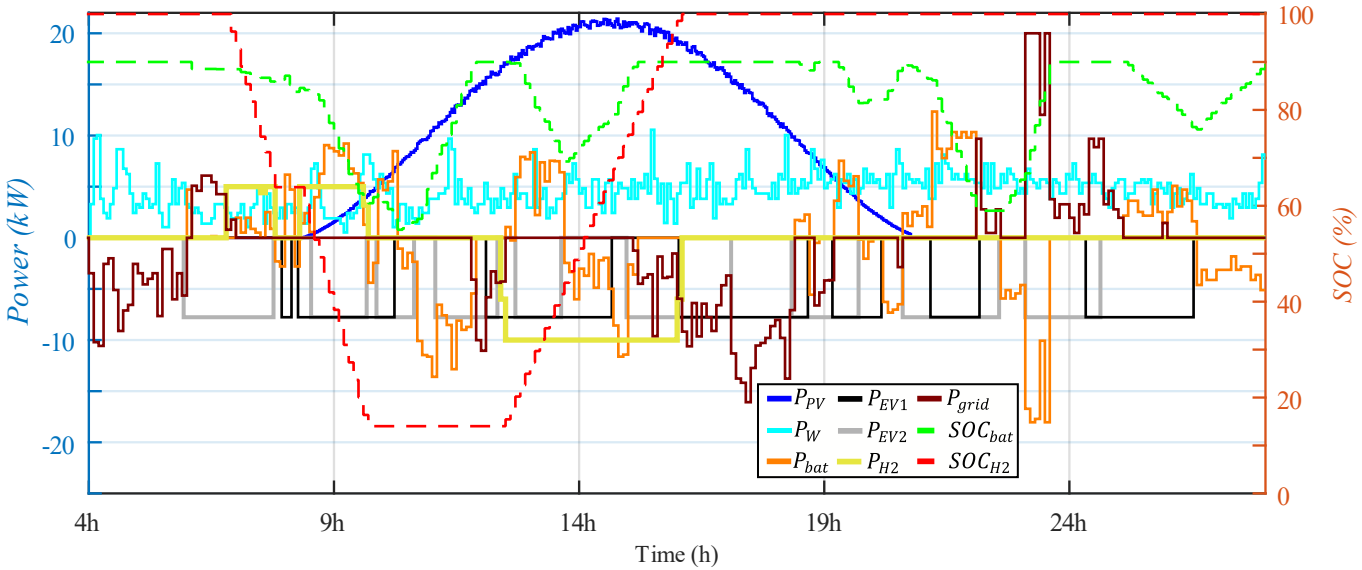

Fig. 2. 27. Power and SOC profiles obtained for scenario 11 and electric vehicle charging station application.

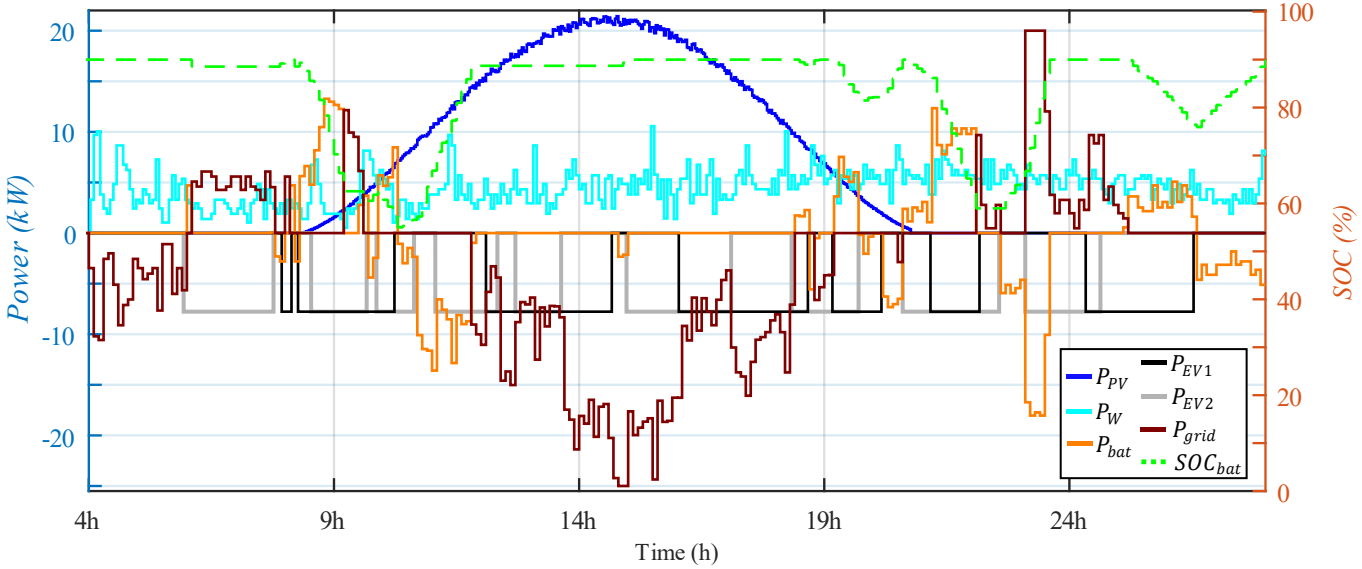

Fig. 2. 28. Power and SOC profiles obtained for scenario 11 and electric vehicle charging station application.

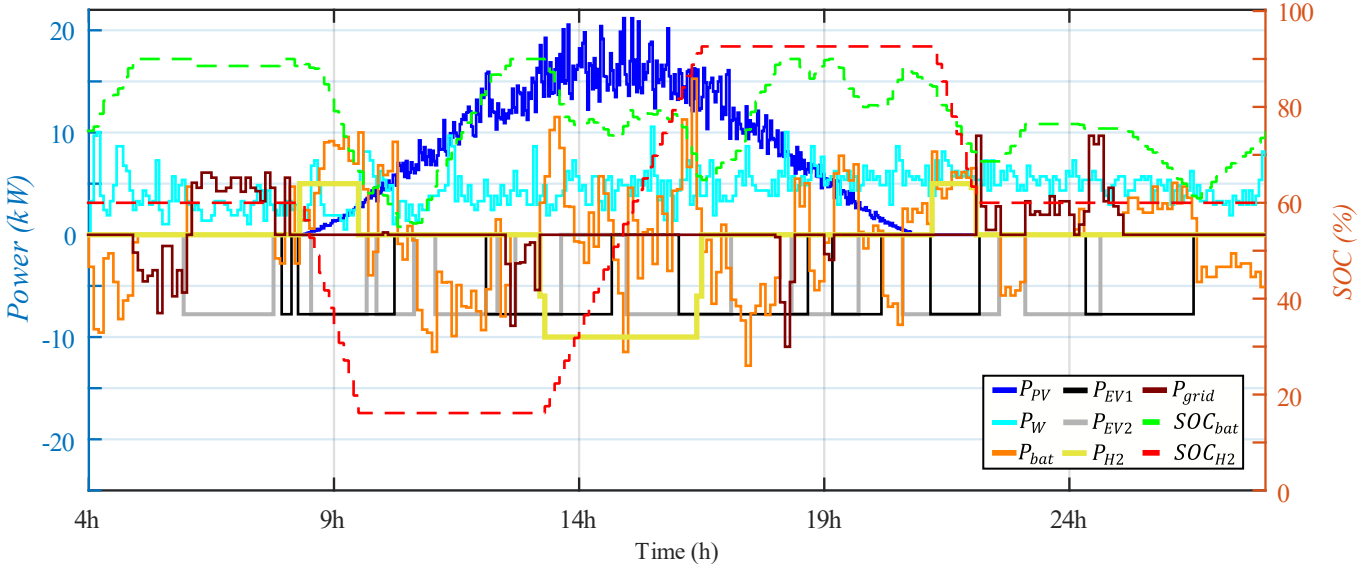

Fig. 2. 29. Power and SOC profiles obtained for scenario 12 and electric vehicle charging station application.

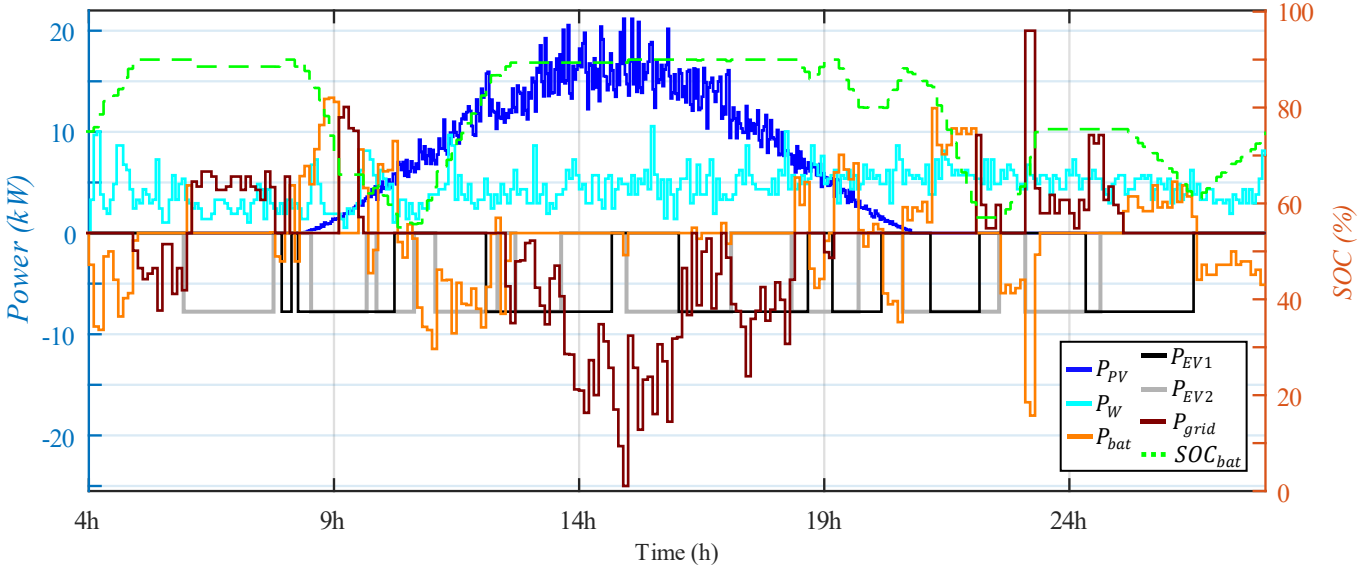

Fig. 2. 30. Power and SOC profiles obtained for scenario 12 and electric vehicle charging station application.

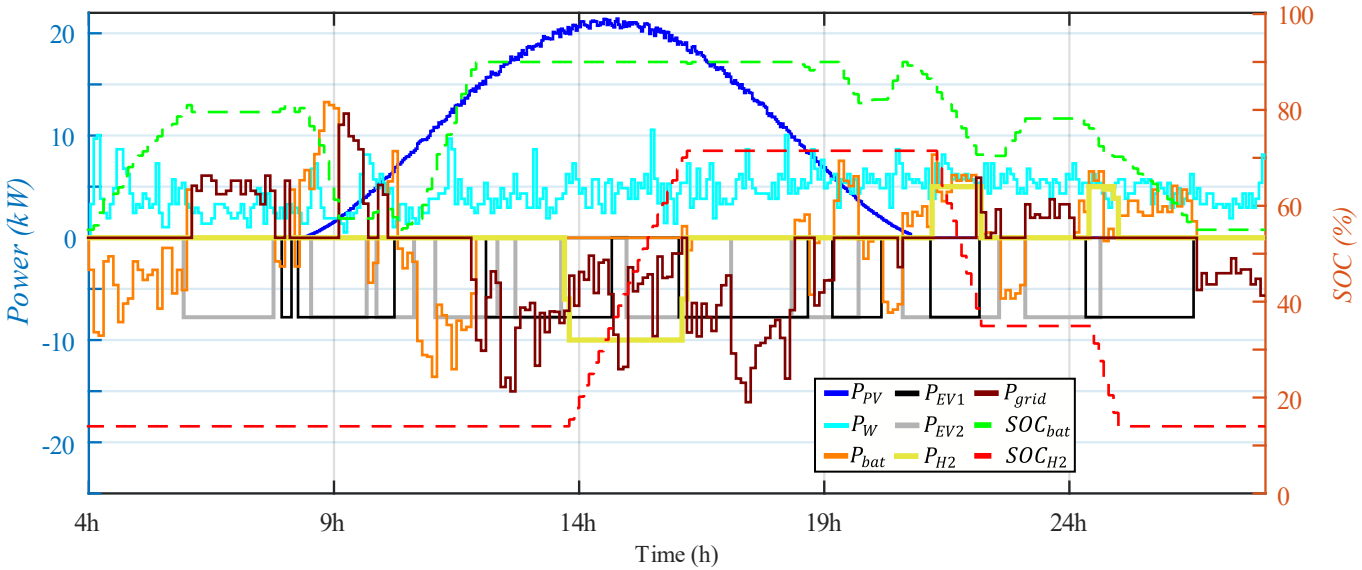

Fig. 2. 31. Power and SOC profiles obtained for scenario 13 and electric vehicle charging station application.

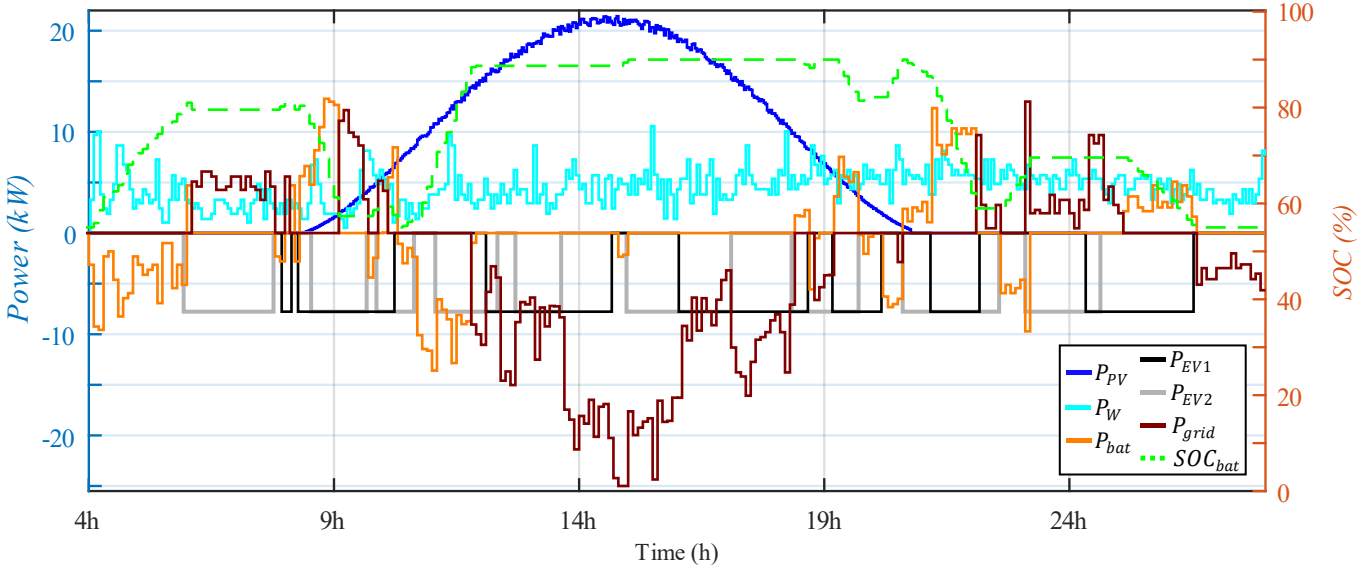

Fig. 2. 32. Power and SOC profiles obtained for scenario 13 and electric vehicle charging station application.

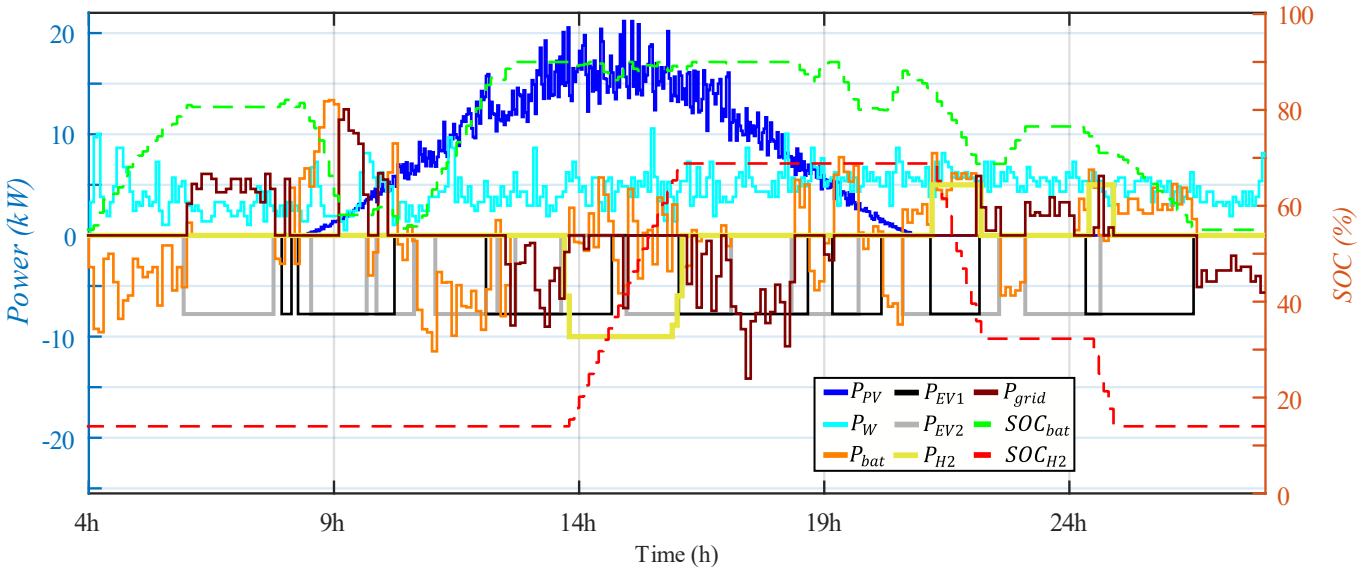

Fig. 2. 33. Power and SOC profiles obtained for scenario 14 and electric vehicle charging station application.

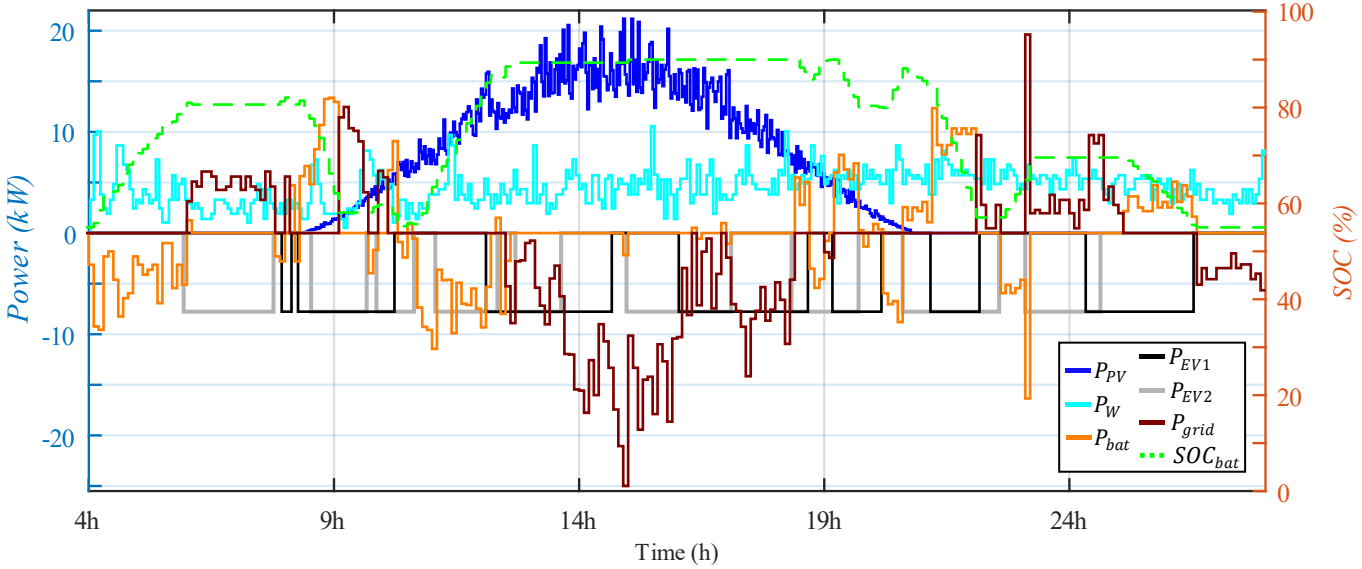

Fig. 2. 34. Power and SOC profiles obtained for scenario 14 and electric vehicle charging station application.

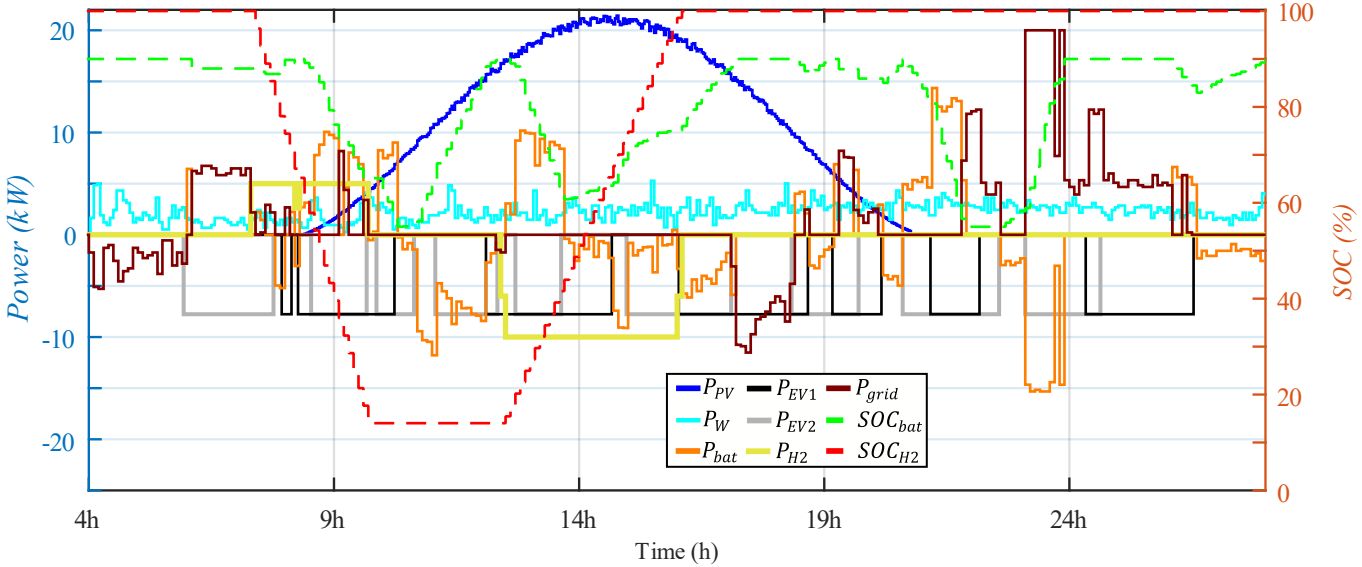

Fig. 2. 35. Power and SOC profiles obtained for scenario 15 and electric vehicle charging station application.

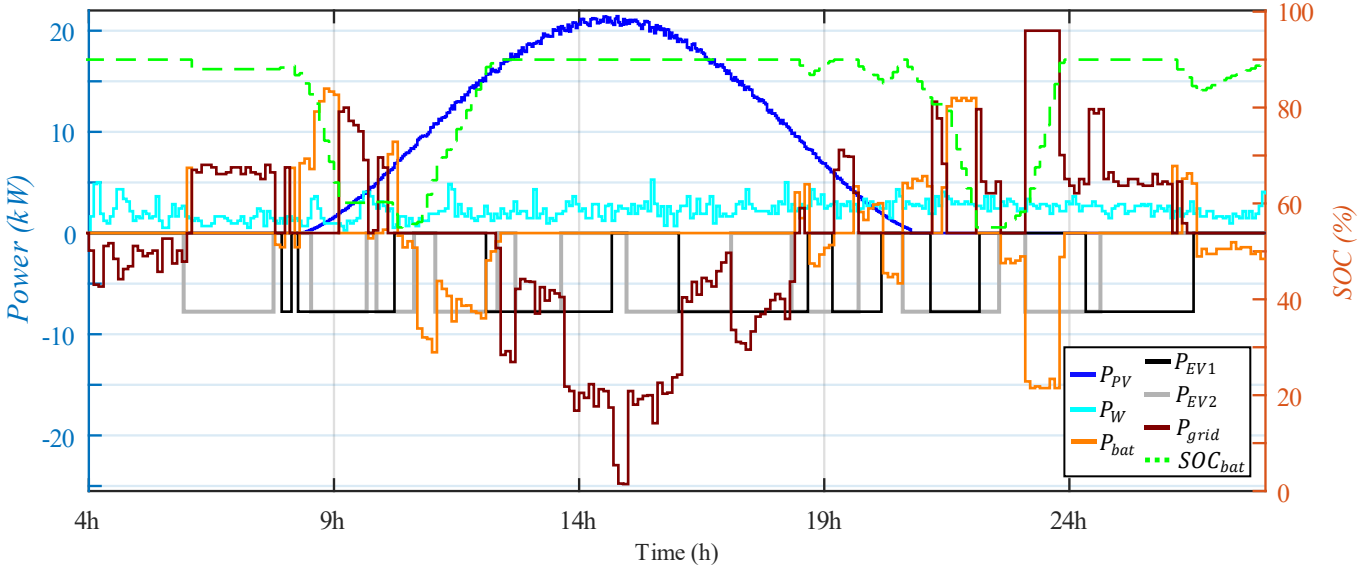

Fig. 2. 36. Power and SOC profiles obtained for scenario 15 and electric vehicle charging station application.

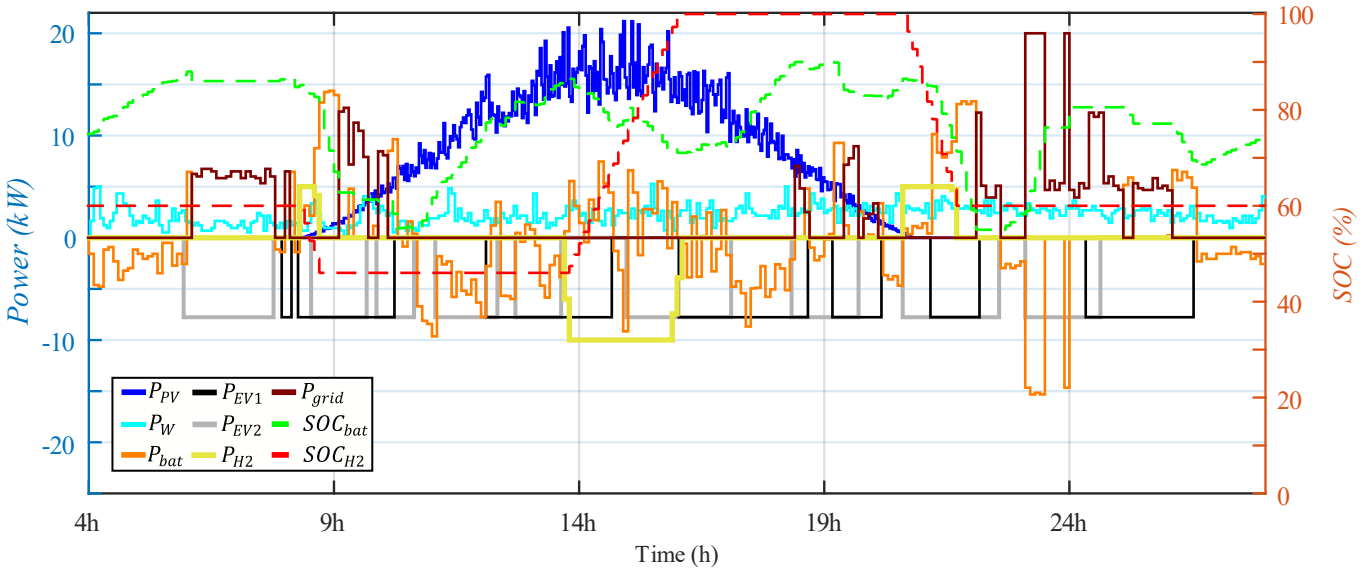

Fig. 2. 37. Power and SOC profiles obtained for scenario 16 and electric vehicle charging station application.

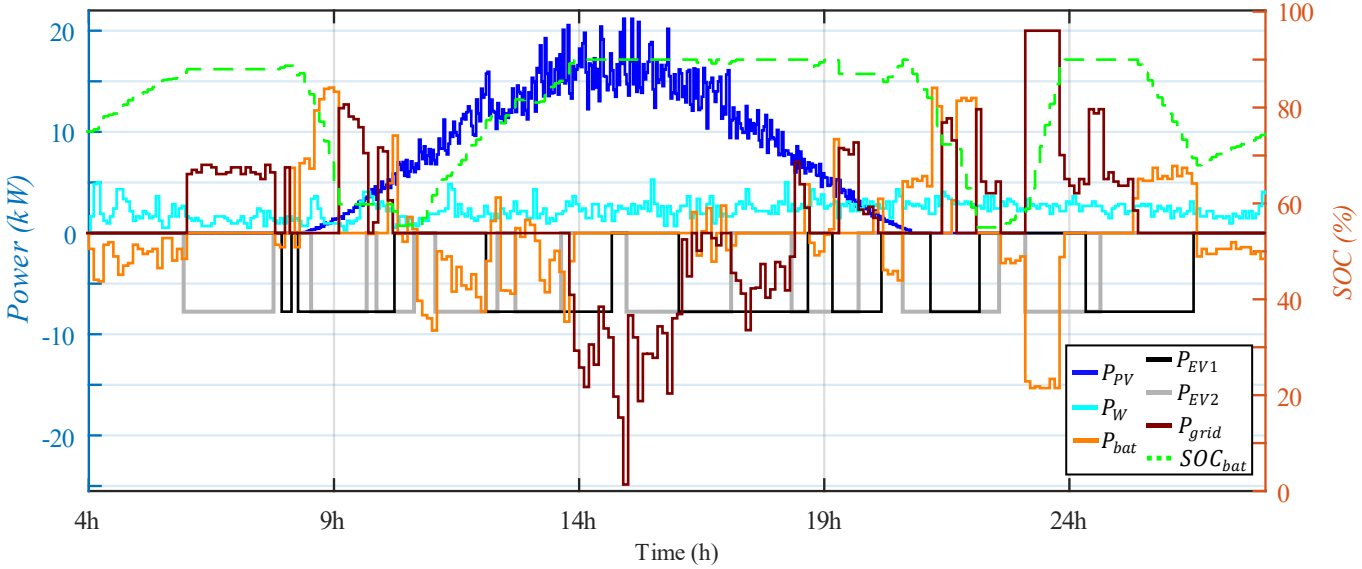

Fig. 2. 38. Power and SOC profiles obtained for scenario 16 and electric vehicle charging station application.

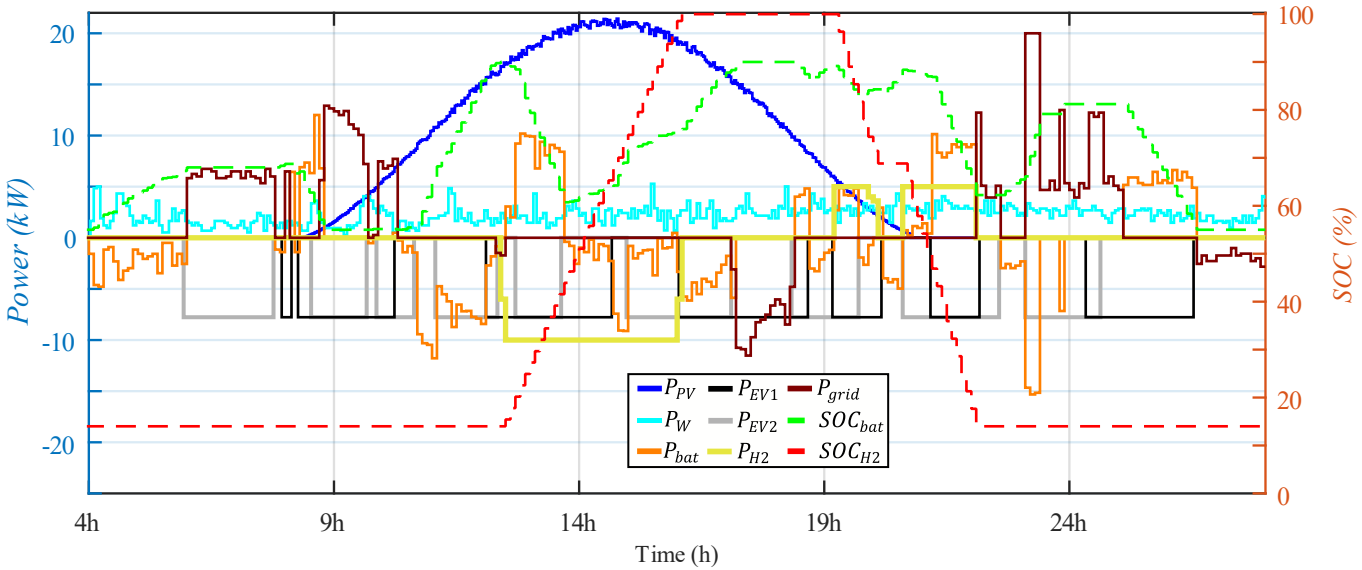

Fig. 2. 39. Power and SOC profiles obtained for scenario 17 and electric vehicle charging station application.

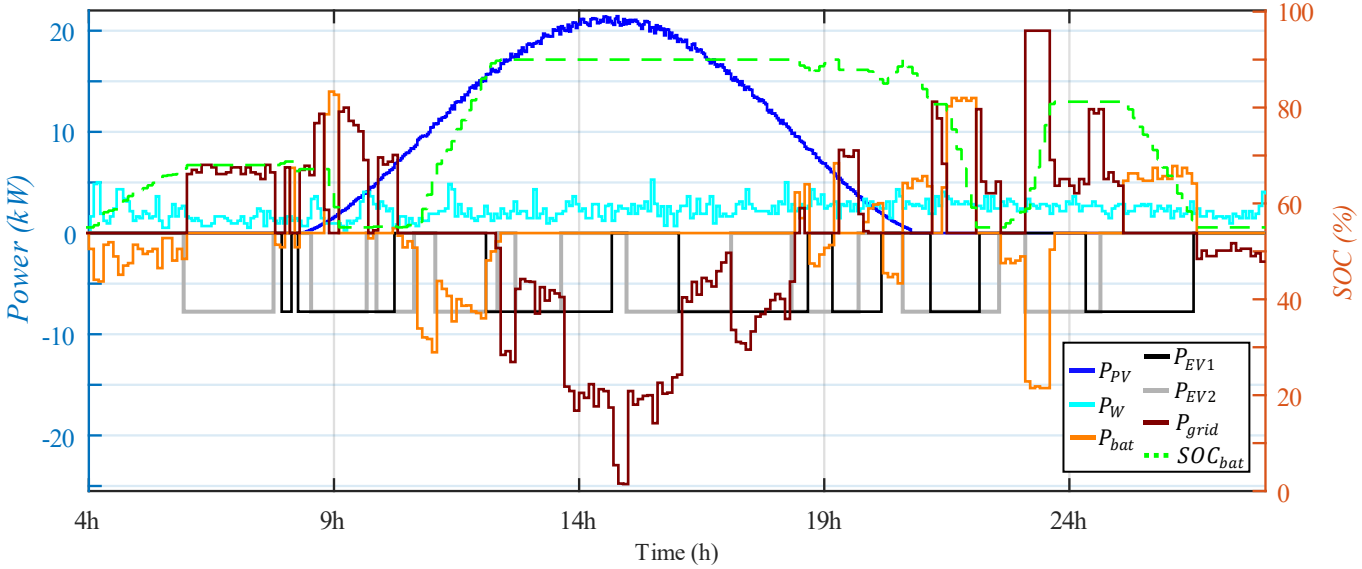

Fig. 2. 40. Power and SOC profiles obtained for scenario 17 and electric vehicle charging station application.

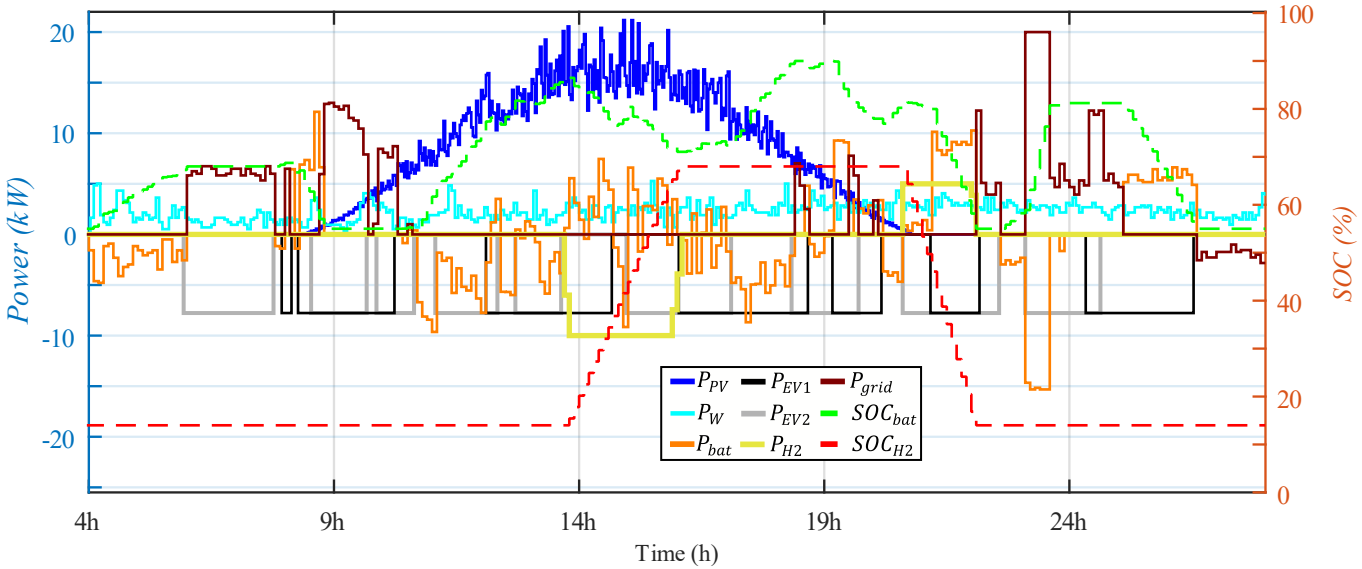

Fig. 2. 41. Power and SOC profiles obtained for scenario 18 and electric vehicle charging station application.

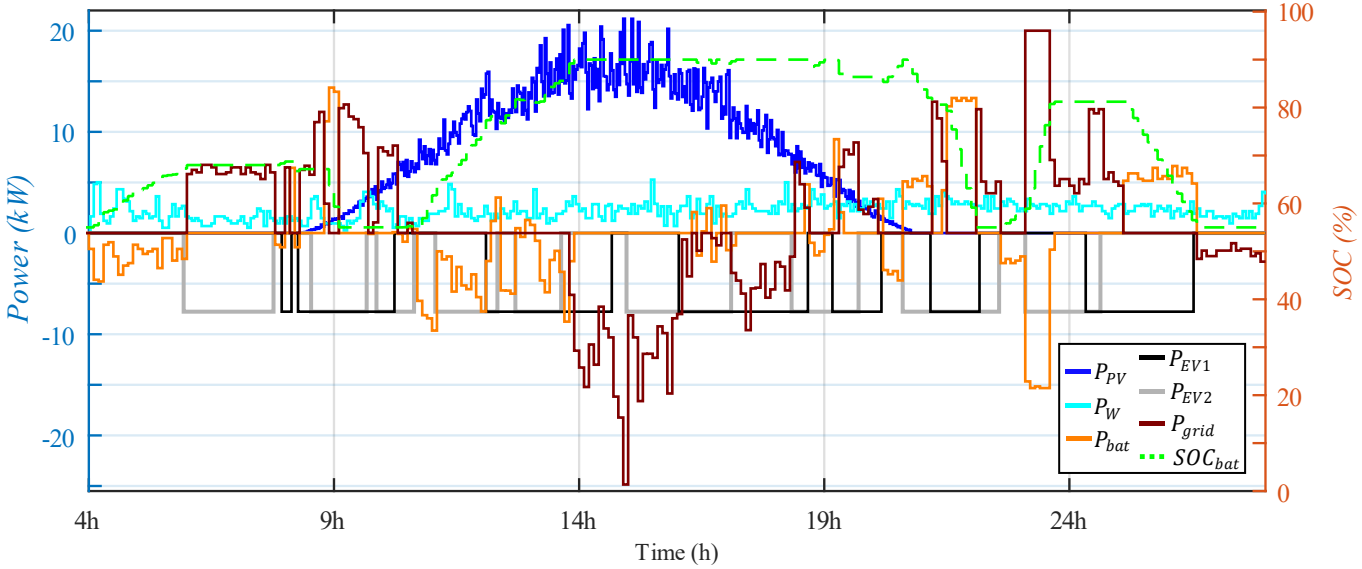

Fig. 2. 42. Power and SOC profiles obtained for scenario 18 and electric vehicle charging station application.

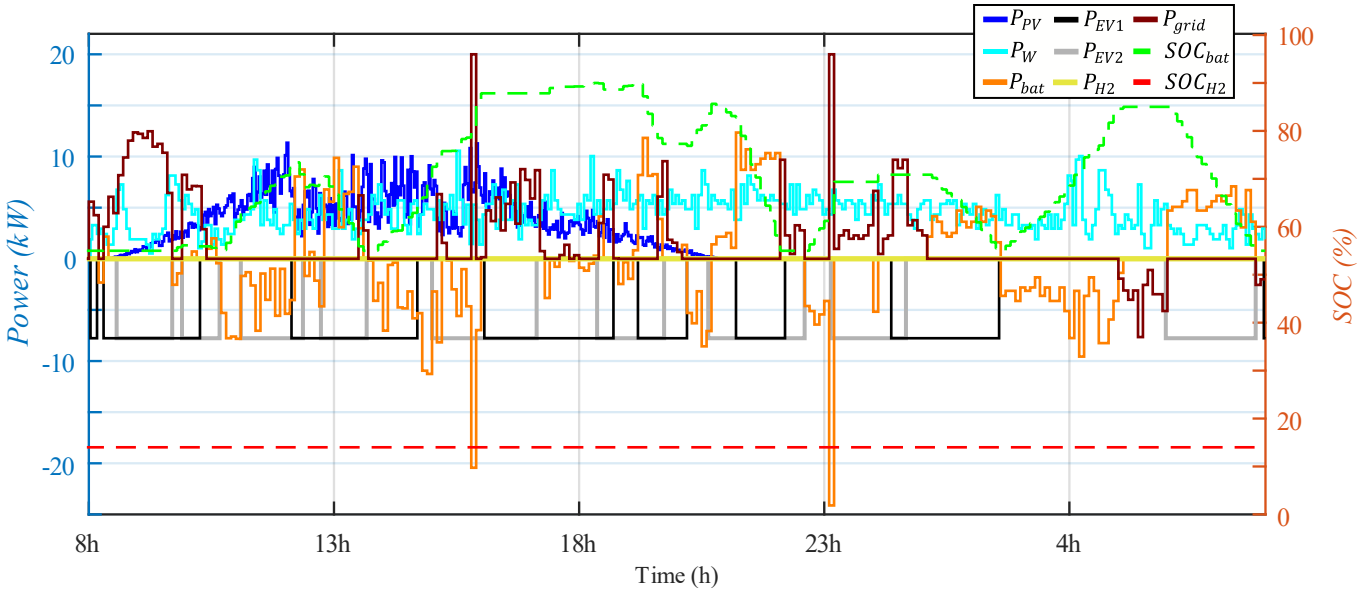

Fig. 2. 43. Power and SOC profiles obtained for scenario 19 and electric vehicle charging station application.

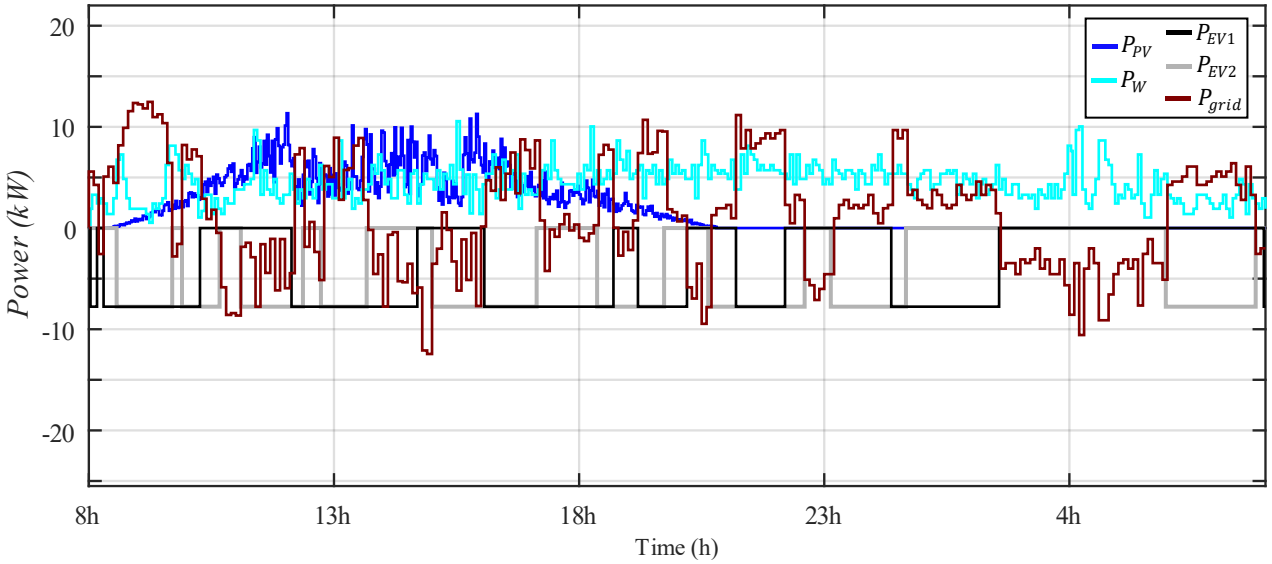

Fig. 2. 44. Power and SOC profiles obtained for scenario 19 and 20 and electric vehicle charging station application.

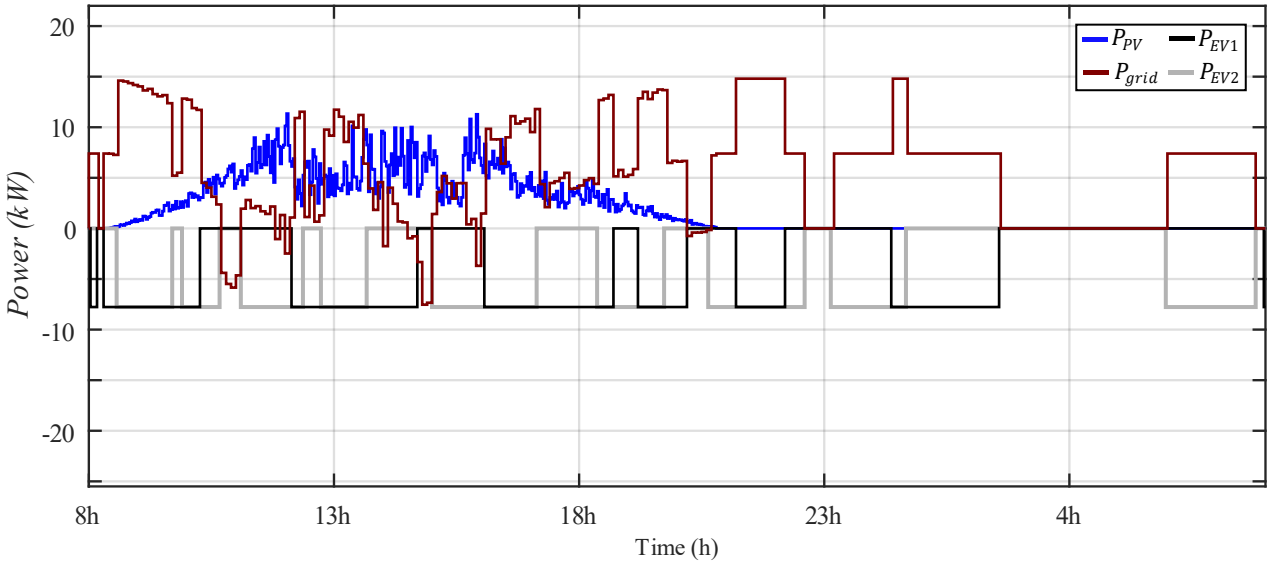

Fig. 2. 45. Power and SOC profiles obtained for scenario 19, 20 and 21 and electric vehicle charging station application.

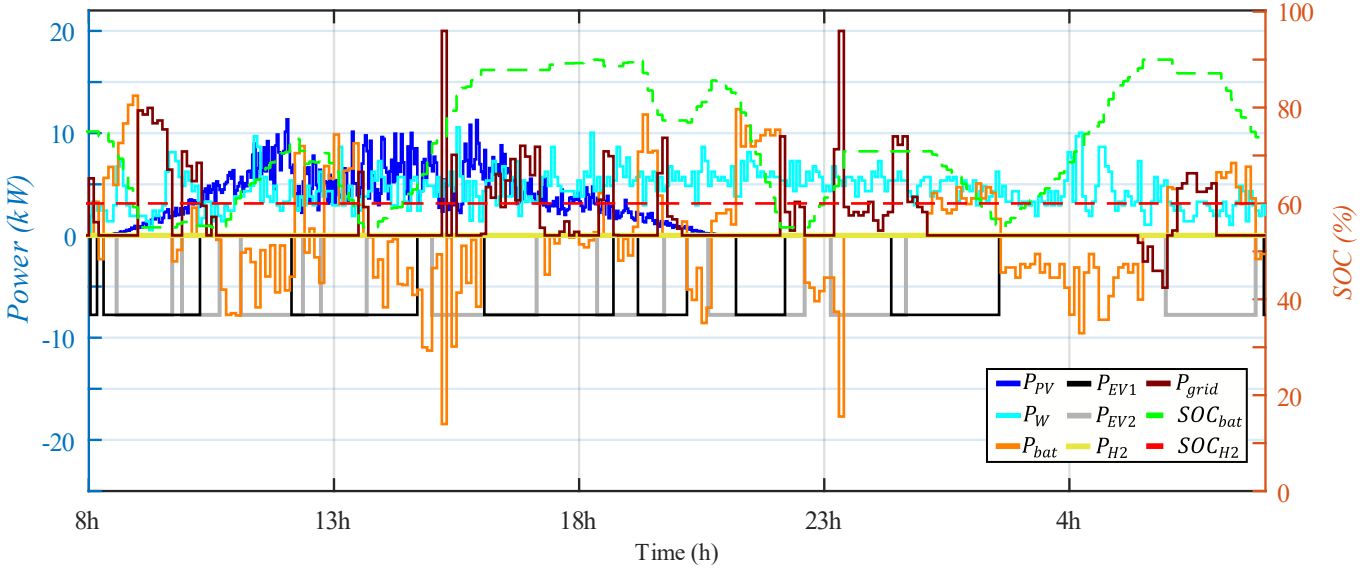

Fig. 2. 46. Power and SOC profiles obtained for scenario 20 and electric vehicle charging station application.

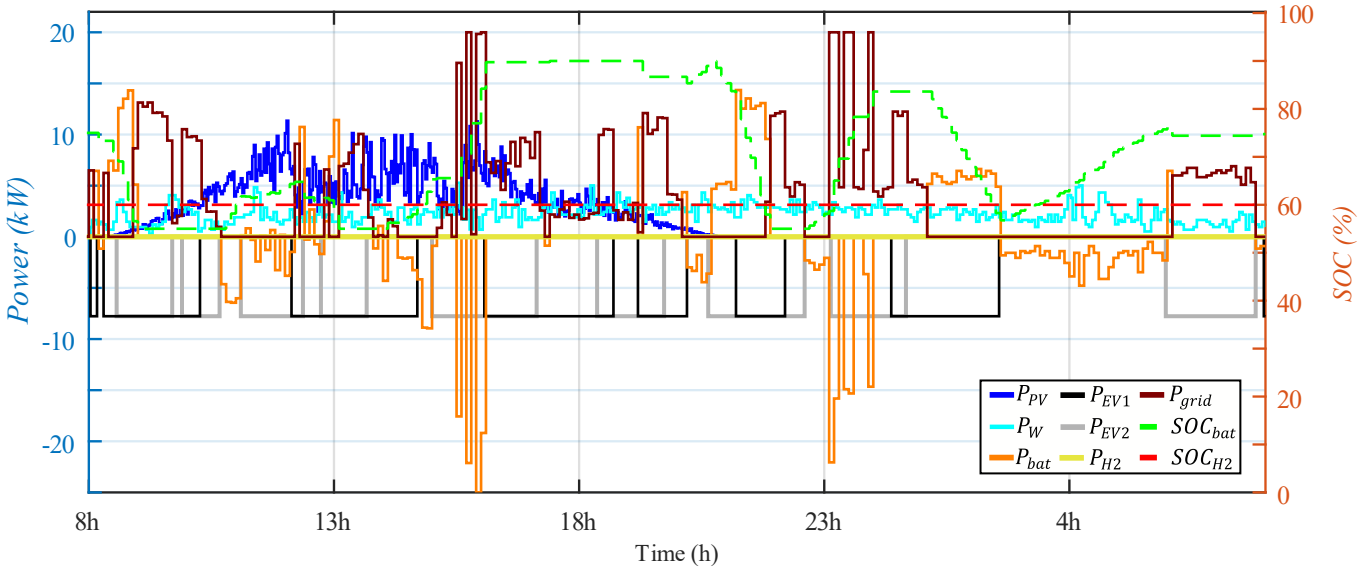

Fig. 2. 47. Power and SOC profiles obtained for scenario 21 and electric vehicle charging station application.

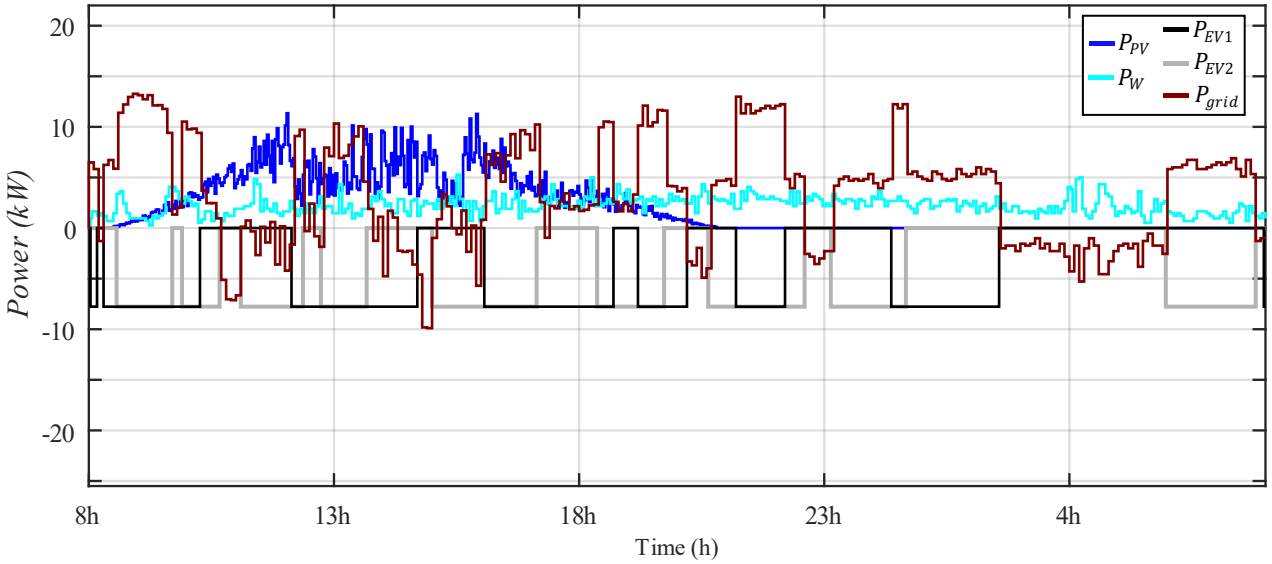

Fig. 2. 48. Power and SOC profiles obtained for scenario 21 and electric vehicle charging station application.

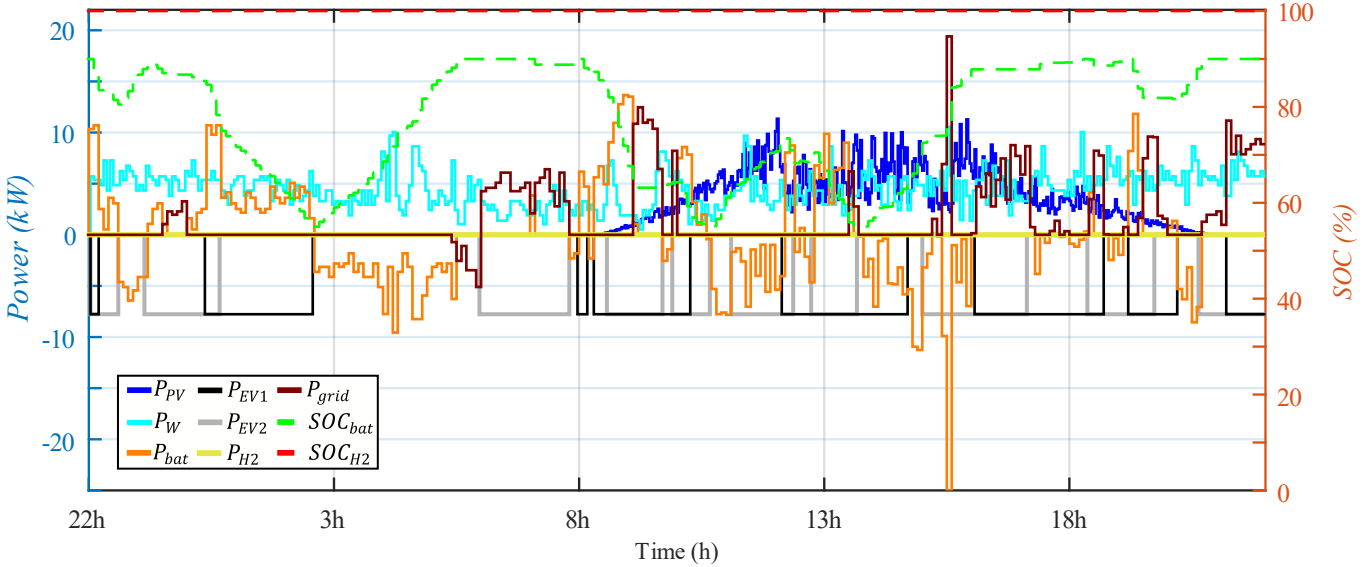

Fig. 2. 49. Power and SOC profiles obtained for scenario 22 and electric vehicle charging station application.

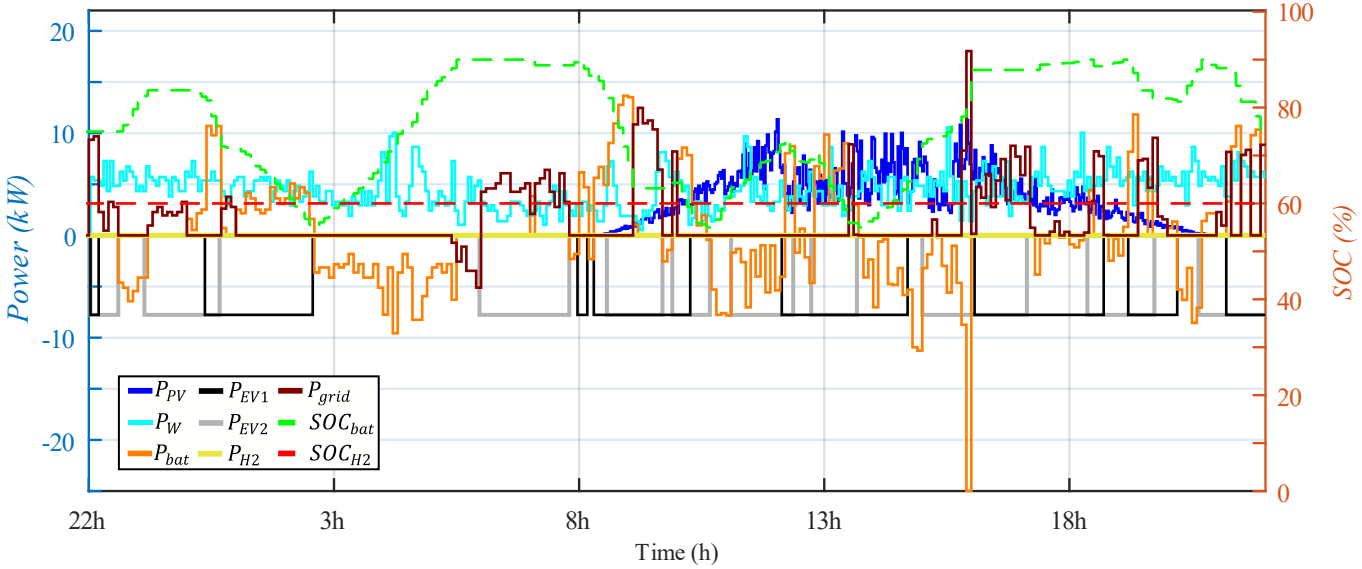

Fig. 2. 50. Power and SOC profiles obtained for scenario 23 and electric vehicle charging station application.

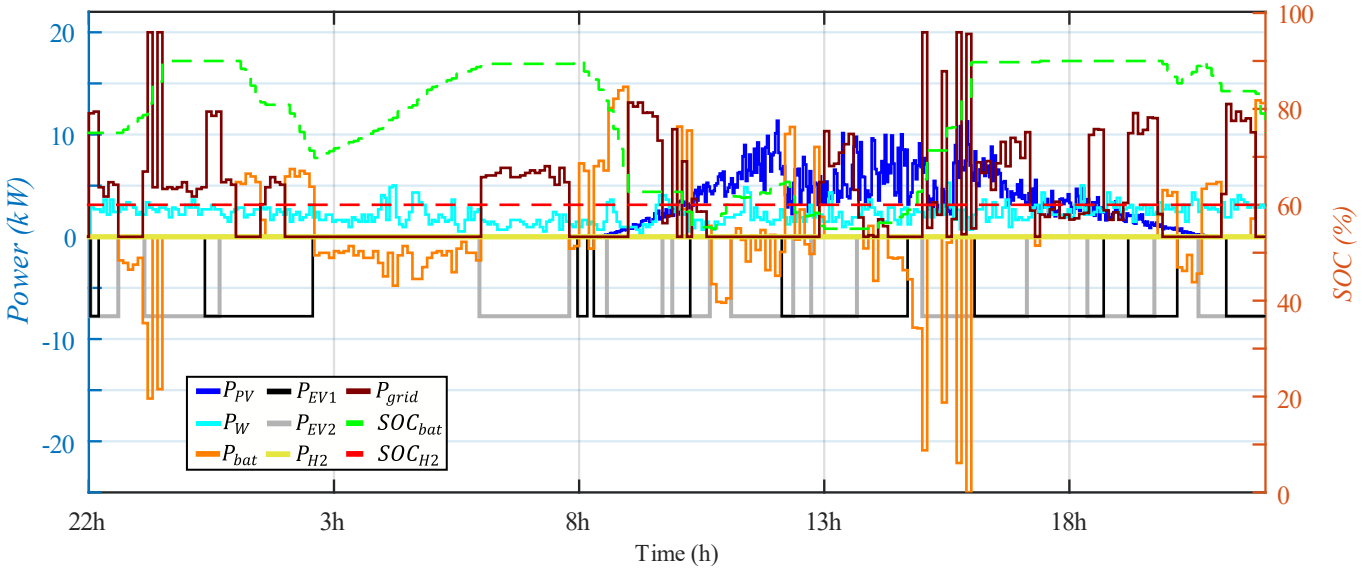

Fig. 2. 51. Power and SOC profiles obtained for scenario 24 and electric vehicle charging station application.

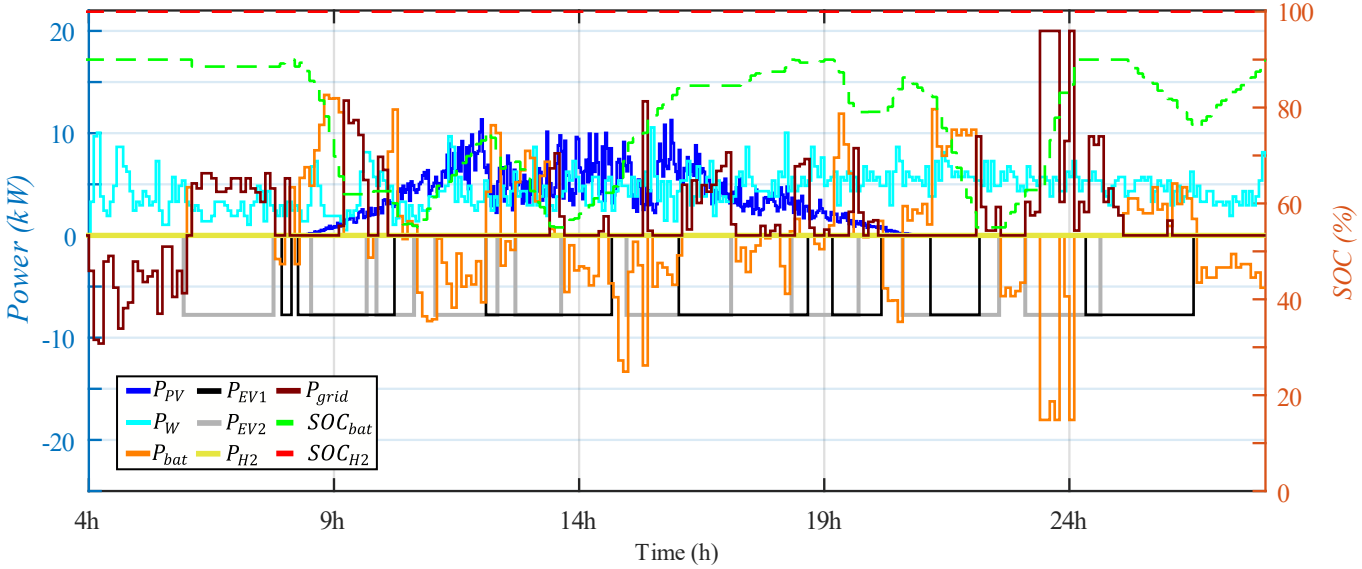

Fig. 2. 52. Power and SOC profiles obtained for scenario 25 and electric vehicle charging station application.

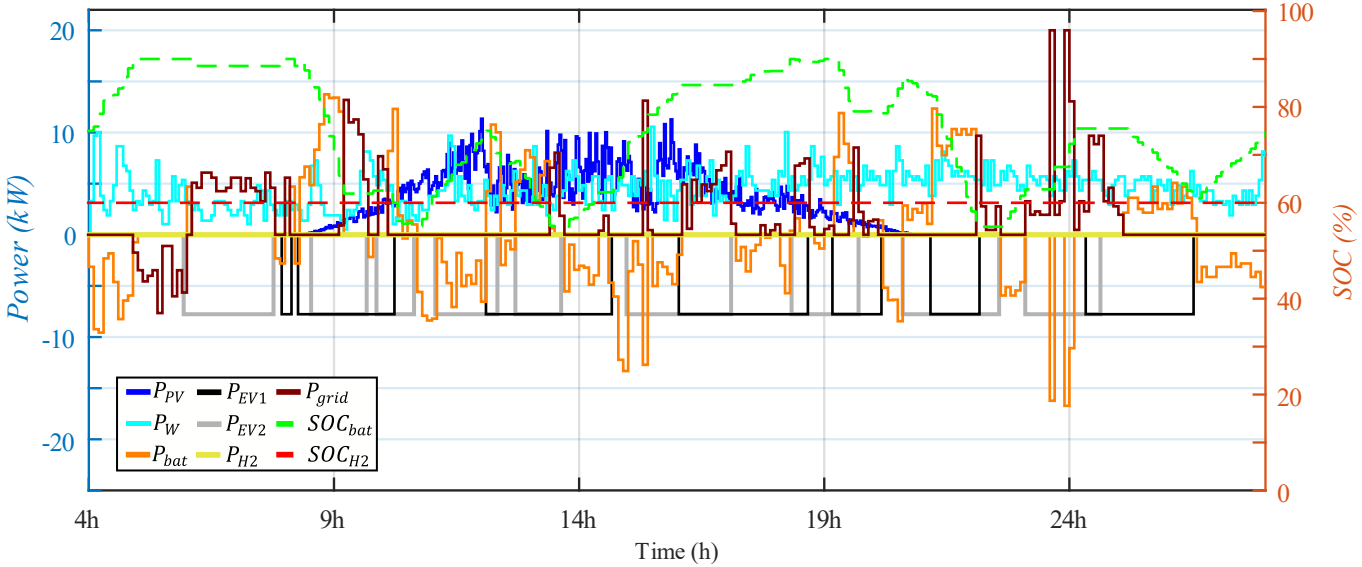

Fig. 2. 53. Power and SOC profiles obtained for scenario 26 and electric vehicle charging station application.

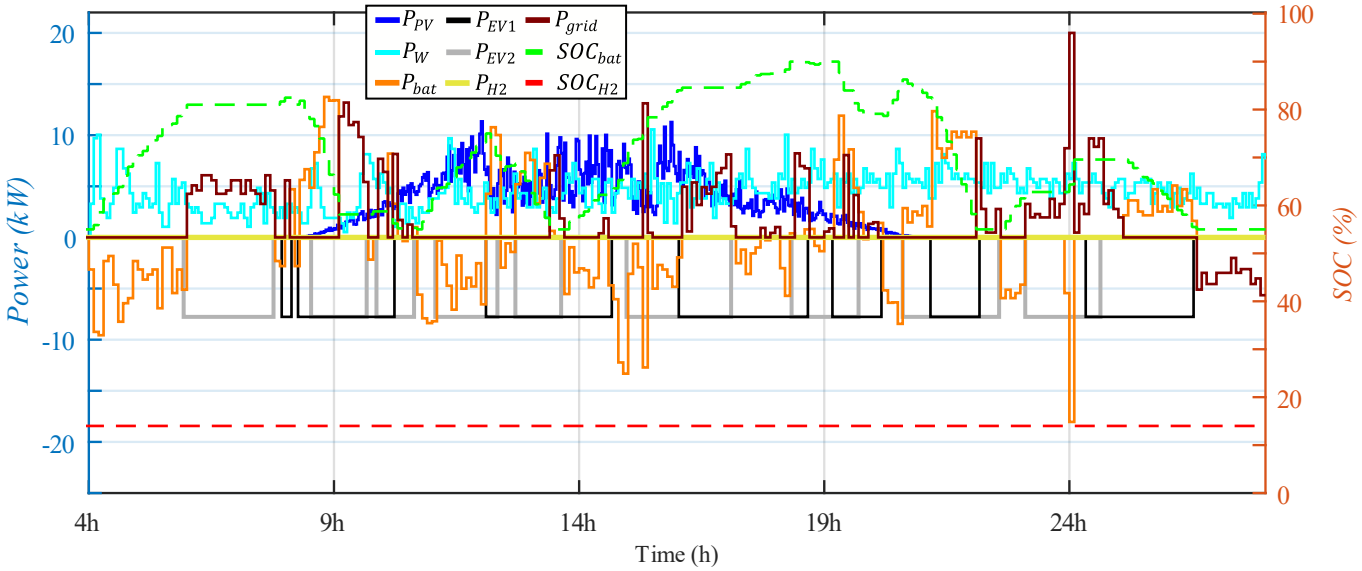

Fig. 2. 54. Power and SOC profiles obtained for scenario 27 and electric vehicle charging station application.

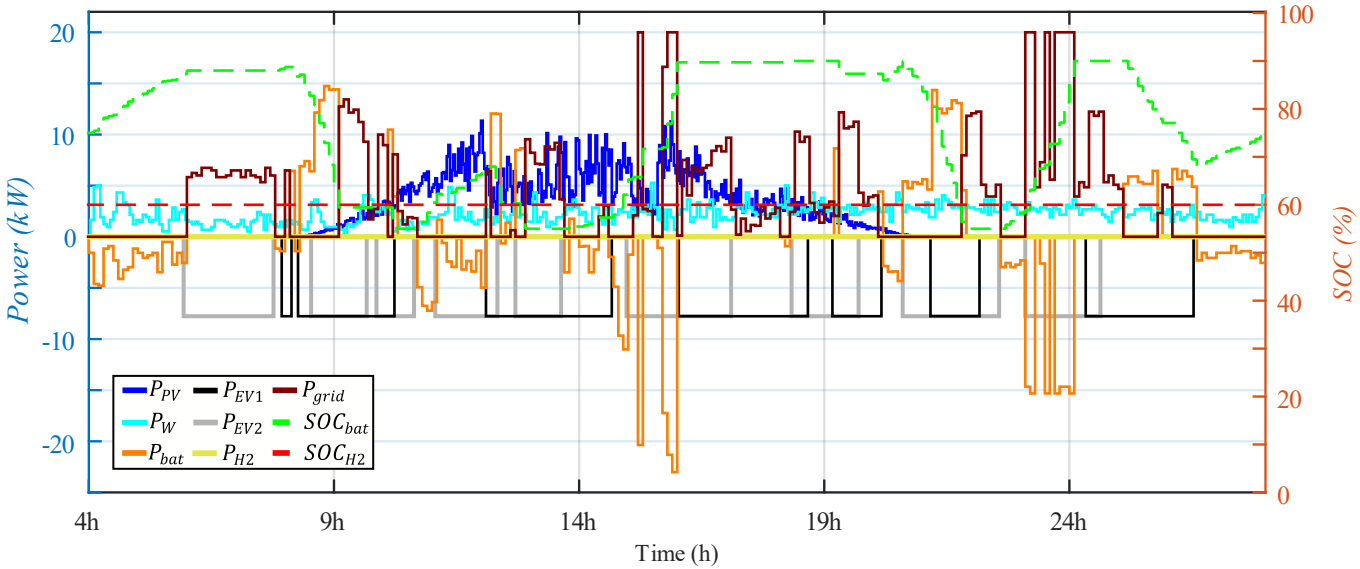

Fig. 2. 55. Power and SOC profiles obtained for scenario 28 and electric vehicle charging station application.

Table 2. Results obtained in the microgrid architecture for electric vehicle charging station application (case 2, Fig. 1). $PH = 24\ h.\ T_s = 0.1\ h.$ (360 $sec.$).

Scenario			Cost									Computational cost[2] (sec.)
Number	Day	Initial conditions	$Cost_{MPC}$ (€)	$Cost_{MPC}/Cost_{MEG}$ (%)	$Cost_{MPC}^{BSS}$ (€)	$Cost_{MPC}^{BSS}/Cost_{MEG}$ (%)	$Cost_{ren}$ (€)	$Cost_{ren}/Cost_{MEG}$ (%)	$Cost_{ren}^{PV}$ (€)	$Cost_{ren}^{PV}/Cost_{MEG}$ (%)	$Cost_{MEG}$ (€)	
1	Sunny and high wind	Starts at 8h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 14\%$	4.38 Fig. 2. 1	6.46	4.49 Fig. 2. 2	6.63	13.66 Fig. 2. 3	20.16	34.56 Fig. 2. 4	51.01	67.75 Fig. 2. 5	3.59 ($Cost_{MPC}$) 0.70 ($Cost_{MPC}^{BSS}$)
2	Sunny with clouds and high wind	Starts at 8h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 14\%$	6.82 Fig. 2. 6	10.07	6.90 Fig. 2. 7	10.18	13.66 Fig. 2. 8	20.16	38.74 Fig. 2. 9	57.18	67.75 Fig. 2. 5	2.51 ($Cost_{MPC}$) 0.57 ($Cost_{MPC}^{BSS}$)
3	Sunny with clouds and high wind	Starts at 8h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 60\%$	5.73 Fig. 2. 10	8.46	6.00 Fig. 2.11	8.86	16.21 Fig. 2. 8	23.93	38.74 Fig. 2. 9	57.18	67.75 Fig. 2. 5	4.06 ($Cost_{MPC}$) 0.65 ($Cost_{MPC}^{BSS}$)
4	Sunny and high wind	Starts at 8h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 60\%$	3.25 Fig. 2. 12	4.80	3.59 Fig. 2. 13	5.30	23.86 Fig. 2. 3	35.22	34.56 Fig. 2. 4	51.01	67.75 Fig. 2. 5	5.18 ($Cost_{MPC}$) 0.55 ($Cost_{MPC}^{BSS}$)
5	Sunny and low wind	Starts at 8h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 60\%$	15.20 Fig. 2. 14	22.44	16.00 Fig. 2. 15	23.62	23.86 Fig. 2. 16	35.22	34.56 Fig. 2. 4	51.01	67.75 Fig. 2. 5	3.17 ($Cost_{MPC}$) 0.82 ($Cost_{MPC}^{BSS}$)
6	Sunny and high wind	Starts at 22h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$	4.28 Fig. 2. 17	6.32	4.59 Fig. 2. 18	6.77	16.21	23.93	38.74	51.01	67.75	3.65 ($Cost_{MPC}$) 0.77 ($Cost_{MPC}^{BSS}$)
7	Sunny with clouds and high wind	Starts at 22h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$	6.81 Fig. 2. 19	10.05	7.03 Fig. 2. 20	10.38	16.21	23.93	38.74	57.18	67.75	3.78 ($Cost_{MPC}$) 0.75 ($Cost_{MPC}^{BSS}$)
8	Sunny and high wind	Starts at 22h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 60\%$	3.25 Fig. 2. 21	4.80	3.93 Fig. 2. 22	5.80	13.66	20.16	34.56	51.01	67.75	5.24 ($Cost_{MPC}$) 0.59 ($Cost_{MPC}^{BSS}$)
9	Sunny and low wind	Starts at 22h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 60\%$	15.56 Fig. 2. 23	22.97	16.32 Fig. 2. 24	24.09	23.86	35.22	34.56	51.01	67.75	2.98 ($Cost_{MPC}$) 0.64 ($Cost_{MPC}^{BSS}$)
10	Sunny with clouds and high wind	Starts at 22h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 60\%$	5.78 Fig. 2. 25	8.53	6.38 Fig. 2. 26	9.42	16.21	23.93	34.56	57.18	67.75	3.81 ($Cost_{MPC}$) 0.54 ($Cost_{MPC}^{BSS}$)
11	Sunny and high wind	Starts at 4h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$	5.22 Fig. 2. 27	7.70	5.54 Fig. 2. 28	8.18	13.66	20.16	34.56	51.01	67.75	5.60 ($Cost_{MPC}$) 0.69 ($Cost_{MPC}^{BSS}$)

[2] CPU processor Intel Core i7, 3.2 GHz with 16 GB RAM.

12	Sunny with clouds and high wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 60\%$	6.10 Fig. 2. 29	9.00	6.33 Fig. 2. 30	9.34	16.21	23.93	38.74	57.18	67.75	3.96 ($Cost_{MPC}$) 0.57 ($Cost_{MPC}^{BSS}$)
13	Sunny and high wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 14\%$	4.37 Fig. 2. 31	6.45	4.46 Fig. 2. 32	6.58	13.66	20.16	34.56	51.01	67.75	2.75 ($Cost_{MPC}$) 0.59 ($Cost_{MPC}^{BSS}$)
14	Sunny with clouds and high wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 14\%$	6.55 Fig. 2. 33	9.67	6.62 Fig. 2. 34	9.77	16.21	23.93	38.74	57.18	67.75	2.80 ($Cost_{MPC}$) 0.68 ($Cost_{MPC}^{BSS}$)
15	Sunny and low wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 90\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 100\%$	16.95 Fig. 2. 35	25.02	17.26 Fig. 2. 36	25.48	23.86	35.22	34.56	51.01	67.75	3.64 ($Cost_{MPC}$) 0.65 ($Cost_{MPC}^{BSS}$)
16	Sunny with clouds and low wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 60\%$	18.29 Fig. 2. 37	27.00	18.79 Fig. 2. 38	27.73	26.95	39.78	38.74	57.18	67.75	3.23 ($Cost_{MPC}$) 0.58 ($Cost_{MPC}^{BSS}$)
17	Sunny and low wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 14\%$	16.22 Fig. 2. 39	23.94	16.95 Fig. 2. 40	25.02	23.86	35.22	34.56	51.01	67.75	4.73 ($Cost_{MPC}$) 0.83 ($Cost_{MPC}^{BSS}$)
18	Sunny with clouds and low wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 14\%$	19.07 Fig. 2. 41	28.15	19.67 Fig. 2. 42	29.03	26.95	39.78	38.74	57.18	67.75	1.76 ($Cost_{MPC}$) 0.54 ($Cost_{MPC}^{BSS}$)
19	Cloudy and high wind	Starts at 8h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 14\%$	15.19 Fig. 2. 43	22.42	15.19 Fig. 2. 43	22.42	25.32 Fig. 2. 44	37.37	53.27 Fig. 2. 45	78.63	67.75 Fig. 2. 5	0.90 ($Cost_{MPC}$) 0.57 ($Cost_{MPC}^{BSS}$)
20	Cloudy and high wind	Starts at 8h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 60\%$	14.29 Fig. 2. 46	21.09	14.29 Fig. 2. 46	21.09	25.32 Fig. 2. 44	37.37	53.27 Fig. 2. 45	78.63	67.75 Fig. 2. 5	1.27 ($Cost_{MPC}$) 0.60 ($Cost_{MPC}^{BSS}$)
21	Cloudy and low wind	Starts at 8h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 60\%$	31.93 Fig. 2. 47	47.13	31.93 Fig. 2. 47	47.13	38.55 Fig. 2. 48	56.90	53.27 Fig. 2. 45	78.63	67.75 Fig. 2. 5	0.90 ($Cost_{MPC}$) 0.59 ($Cost_{MPC}^{BSS}$)
22	Cloudy and high wind	Starts at 22h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 90\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 100\%$	15.34 Fig. 2. 49	22.64	15.34 Fig. 2. 49	22.64	25.32	37.37	53.27	78.63	67.75	1.04 ($Cost_{MPC}$) 0.63 ($Cost_{MPC}^{BSS}$)
23	Cloudy and high wind	Starts at 22h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 60\%$	14.68 Fig. 2. 50	21.67	14.68 Fig. 2. 50	21.67	25.32	37.37	53.27	78.63	67.75	1.11 ($Cost_{MPC}$) 0.59 ($Cost_{MPC}^{BSS}$)
24	Cloudy and low wind	Starts at 22h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 60\%$	32.29 Fig. 2. 51	47.66	32.29 Fig. 2. 51	47.66	38.55	56.90	53.27	78.63	67.75	0.98 ($Cost_{MPC}$) 0.65 ($Cost_{MPC}^{BSS}$)

25	Cloudy and high wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 90\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 100\%$	15.65 Fig. 2. 52	23.10	15.65 Fig. 2. 52	23.10	25.32	37.37	53.27	78.63	67.75	1.03 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.62 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
26	Cloudy and high wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 60\%$	14.28 Fig. 2. 53	21.08	14.28 Fig. 2. 53	21.08	25.32	37.37	53.27	78.63	67.75	1.40 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.57 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
27	Cloudy and high wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 14\%$	14.58 Fig. 2. 54	21.52	14.58 Fig. 2. 54	21.52	25.32	37.37	53.27	78.63	67.75	0.85 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.80 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
28	Cloudy and low wind	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 60\%$	31.51 Fig. 2. 55	46.51	31.51 Fig. 2. 55	46.51	38.55	56.90	53.27	78.63	67.75	0.91 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.73 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)

3. Microgrid architecture for industrial application (case 3, Fig. 1).

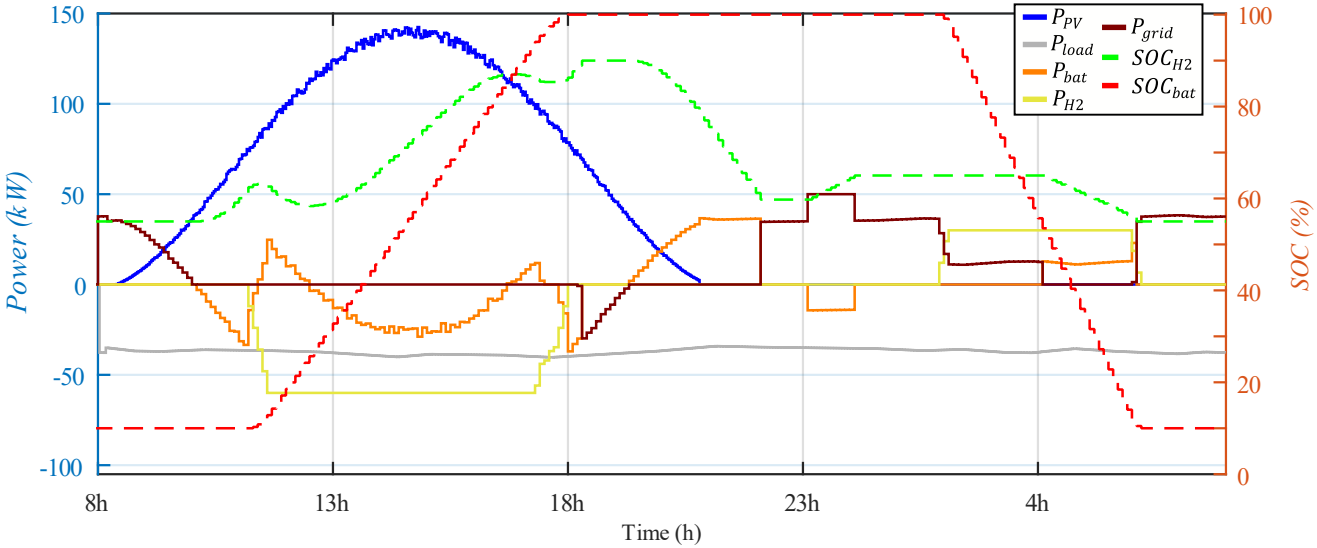

Fig. 3. 1. Power and SOC profiles obtained for scenario 1 and industrial application.

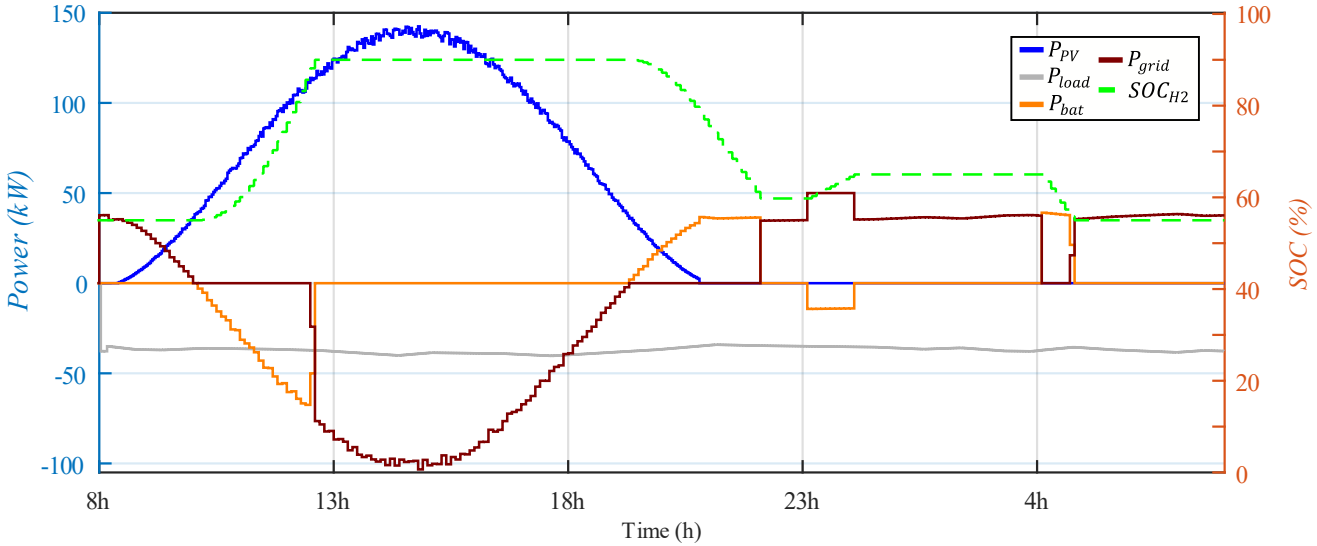

Fig. 3. 2. Power and SOC profiles obtained for scenario 1 and industrial application.

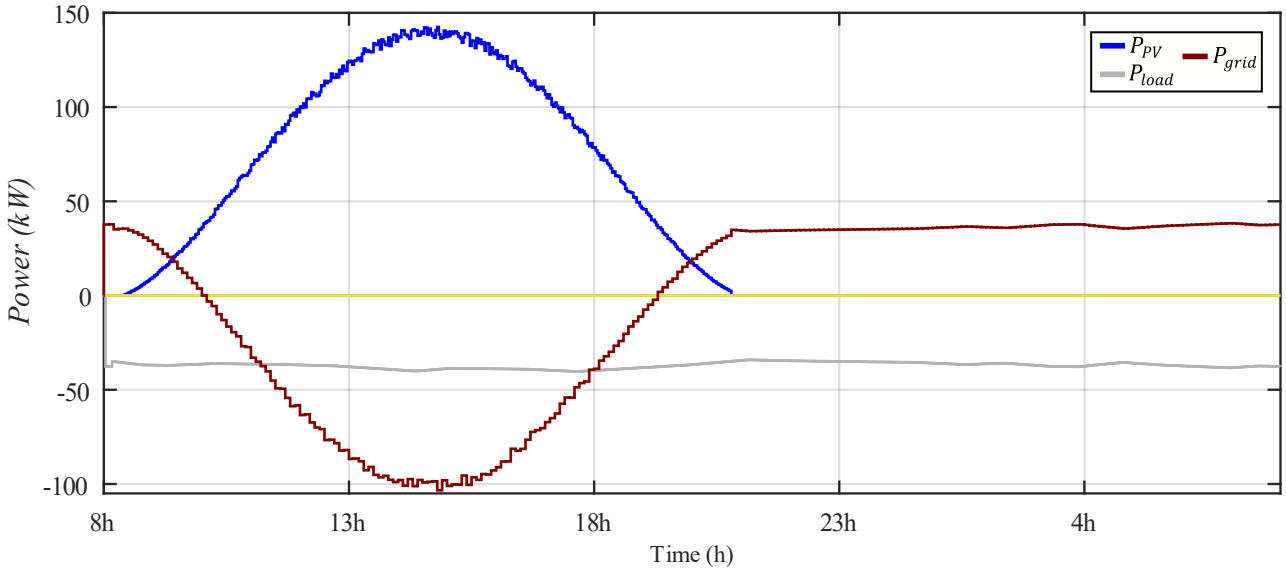

Fig. 3. 3. Power and SOC profiles obtained for scenario 1 and 2 and industrial application.

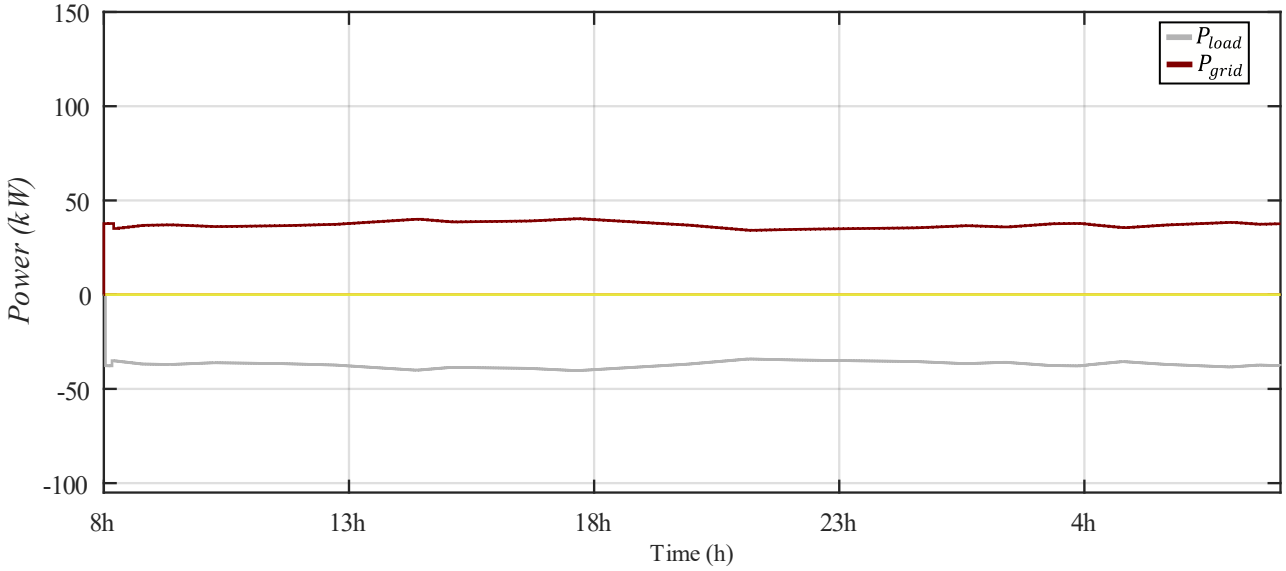

Fig. 3. 4. Power and SOC profiles obtained for scenario 1, 2, 8, 9, 15 and 16 and industrial application.

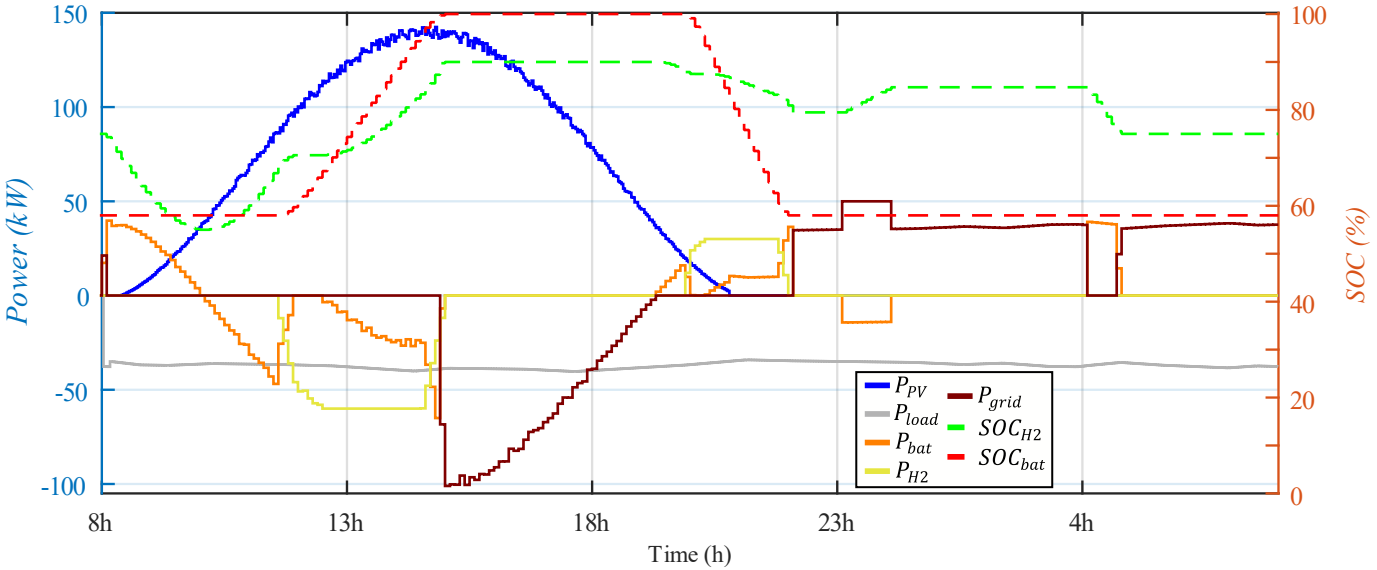

Fig. 3. 5. Power and SOC profiles obtained for scenario 2 and industrial application.

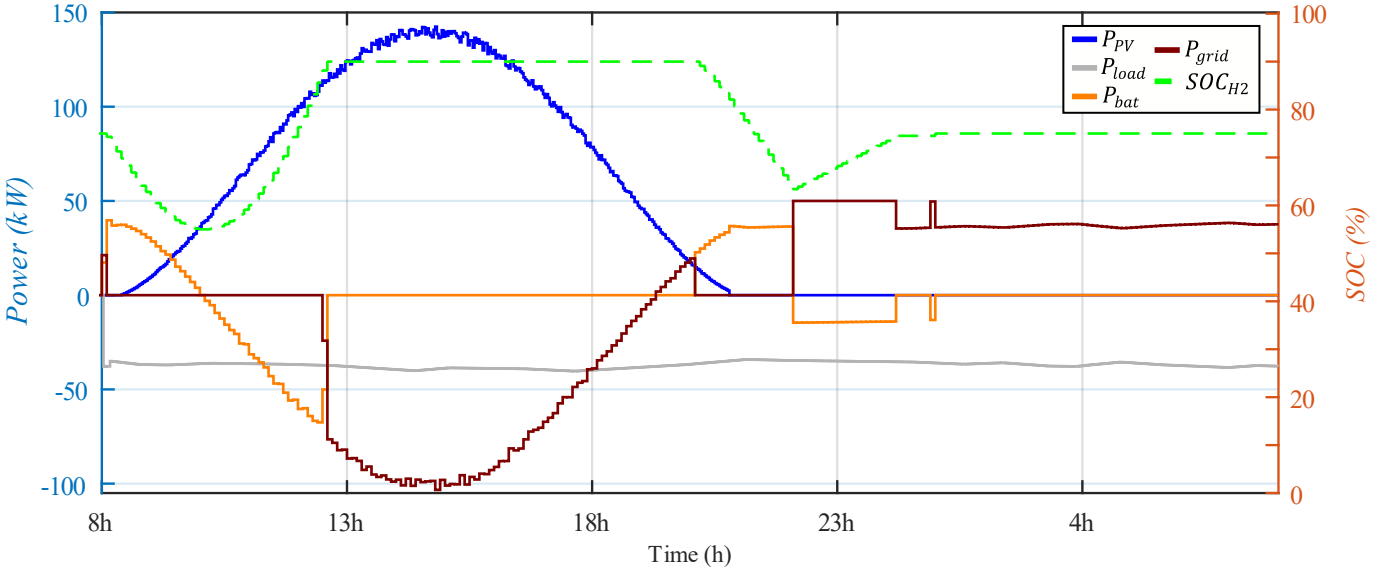

Fig. 3. 6. Power and SOC profiles obtained for scenario 2 and industrial application.

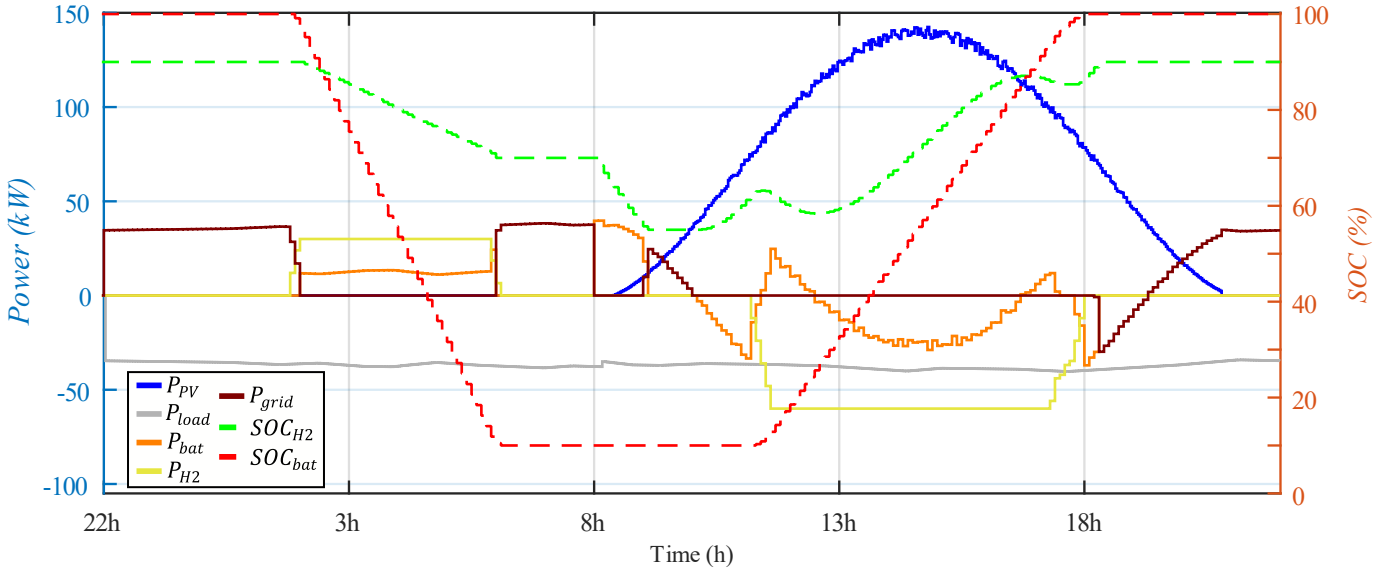

Fig. 3. 7. Power and SOC profiles obtained for scenario 3 and industrial application.

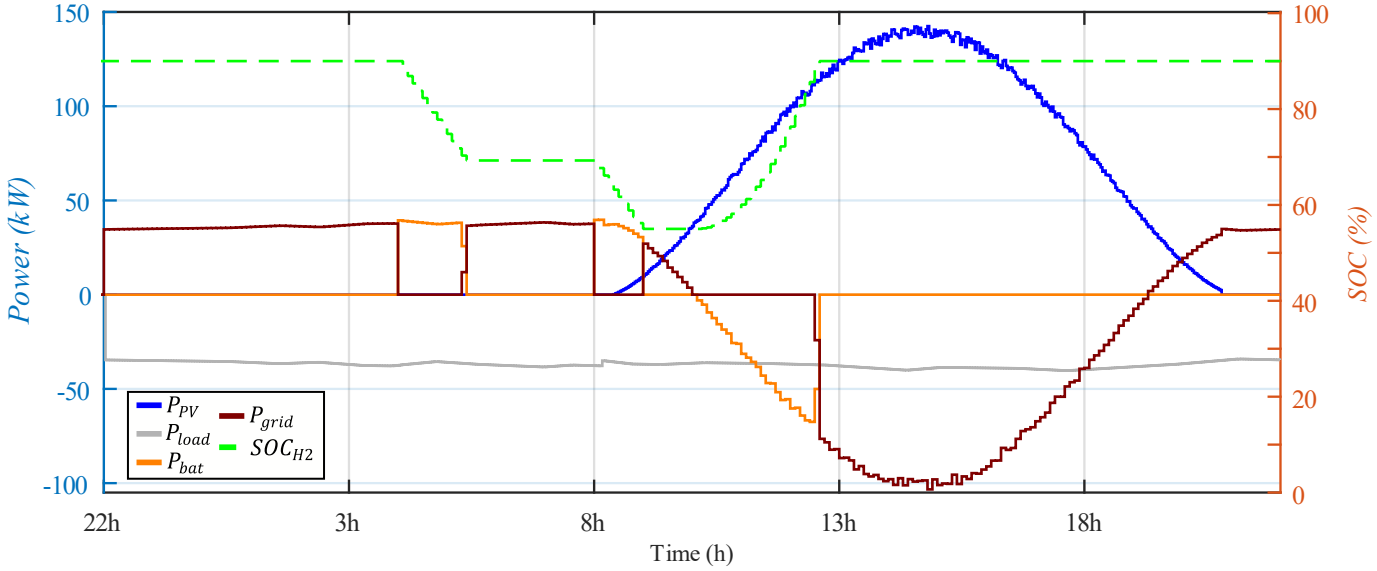

Fig. 3. 8. Power and SOC profiles obtained for scenario 3 and industrial application.

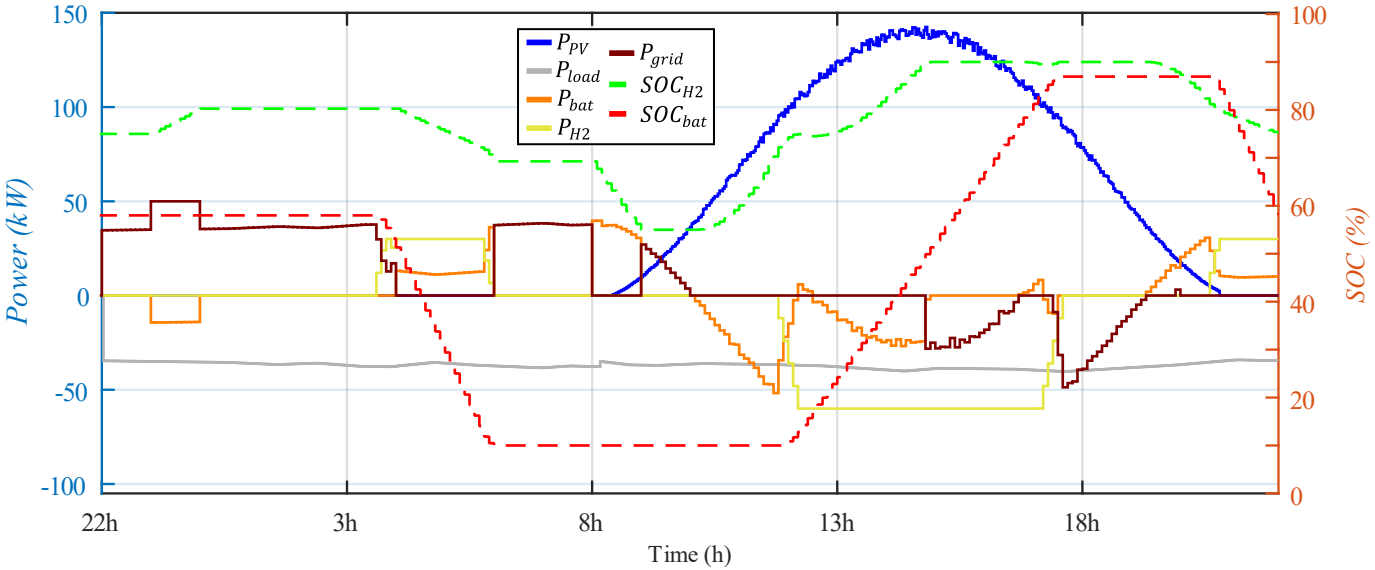

Fig. 3. 9. Power and SOC profiles obtained for scenario 4 and industrial application.

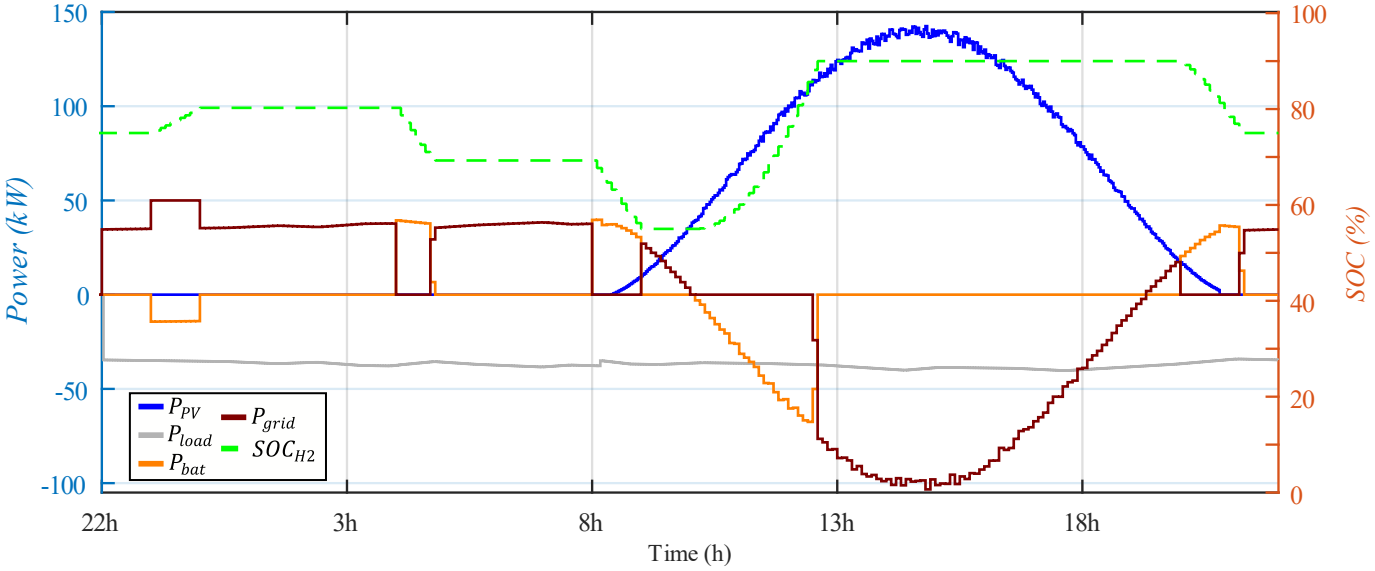

Fig. 3. 10. Power and SOC profiles obtained for scenario 4 and industrial application.

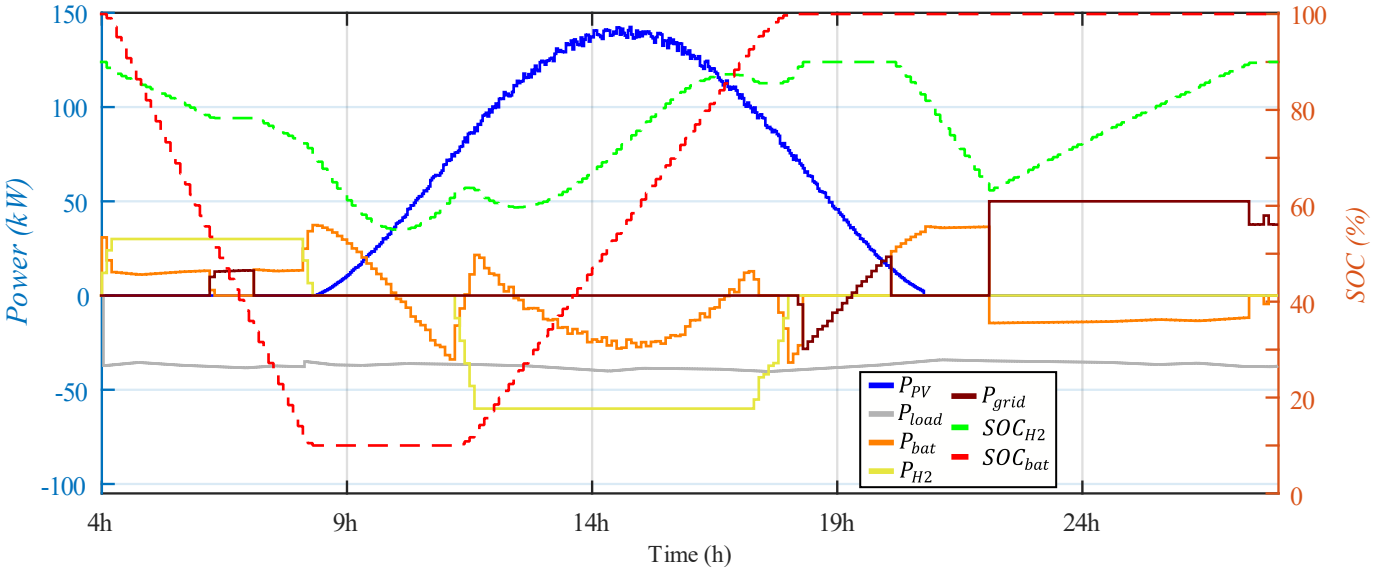

Fig. 3. 11. Power and SOC profiles obtained for scenario 5 and industrial application.

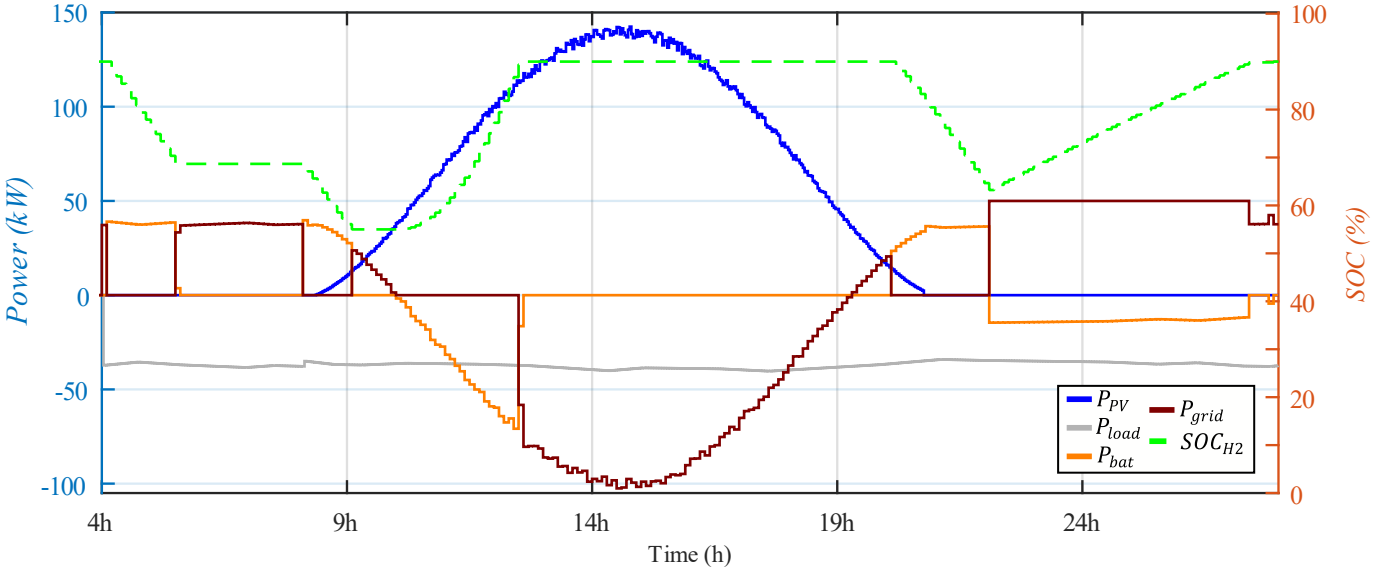

Fig. 3. 12. Power and SOC profiles obtained for scenario 5 and industrial application.

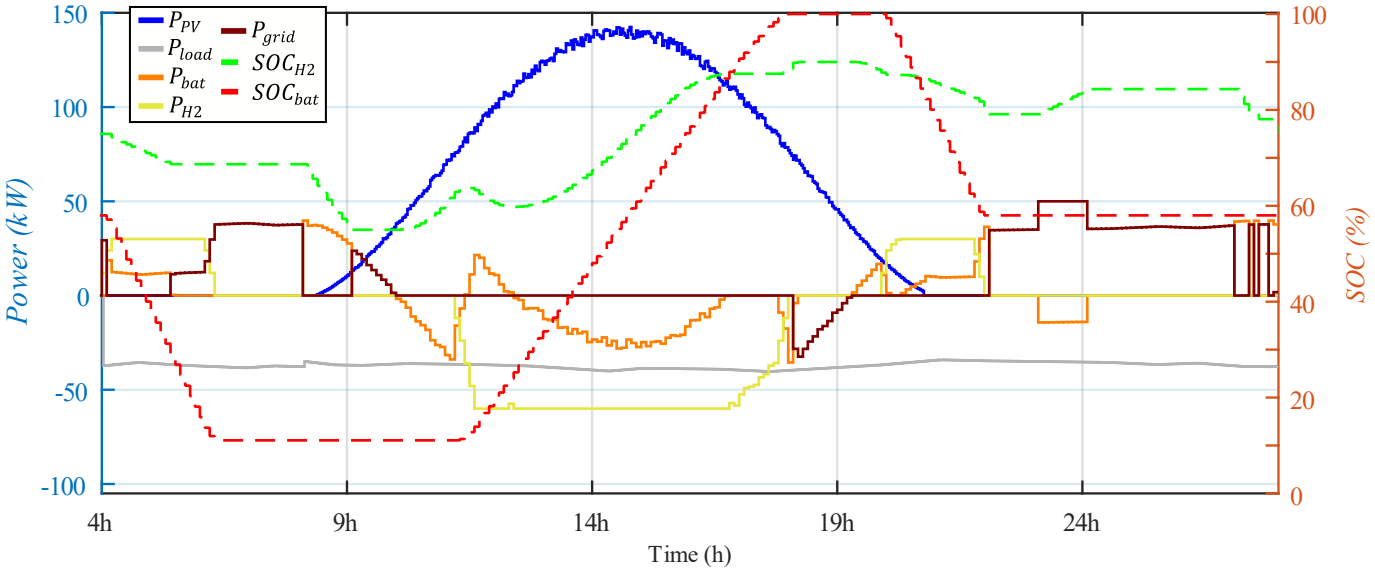

Fig. 3. 13. Power and SOC profiles obtained for scenario 6 and industrial application.

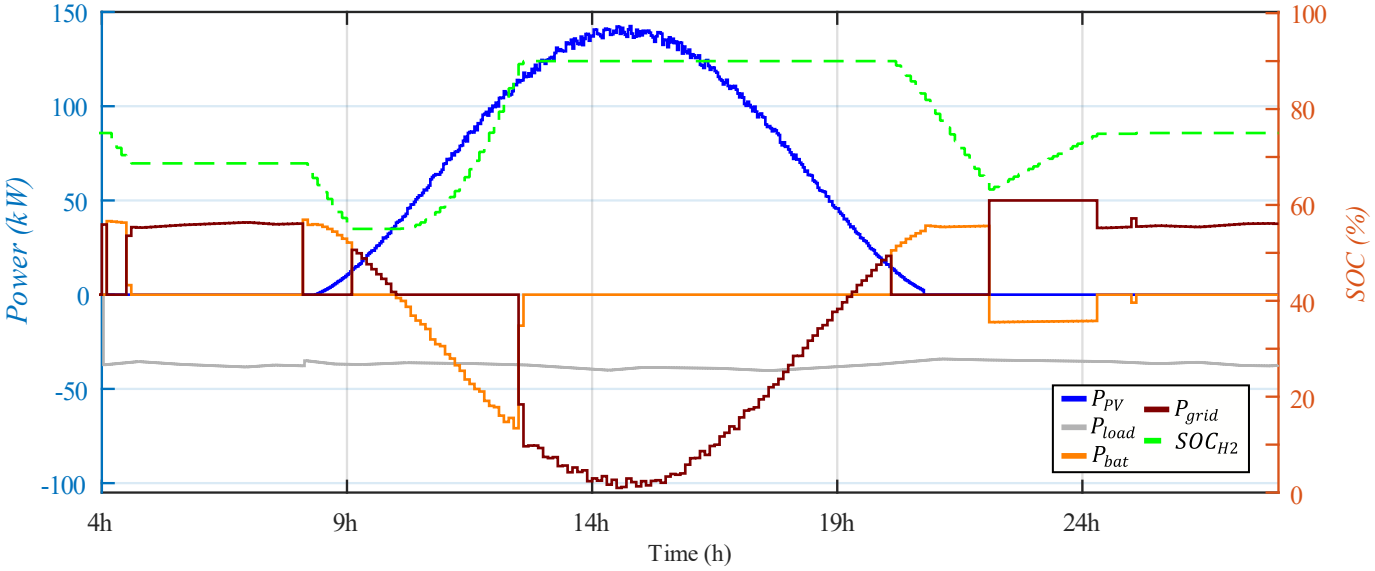

Fig. 3. 14. Power and SOC profiles obtained for scenario 6 and industrial application.

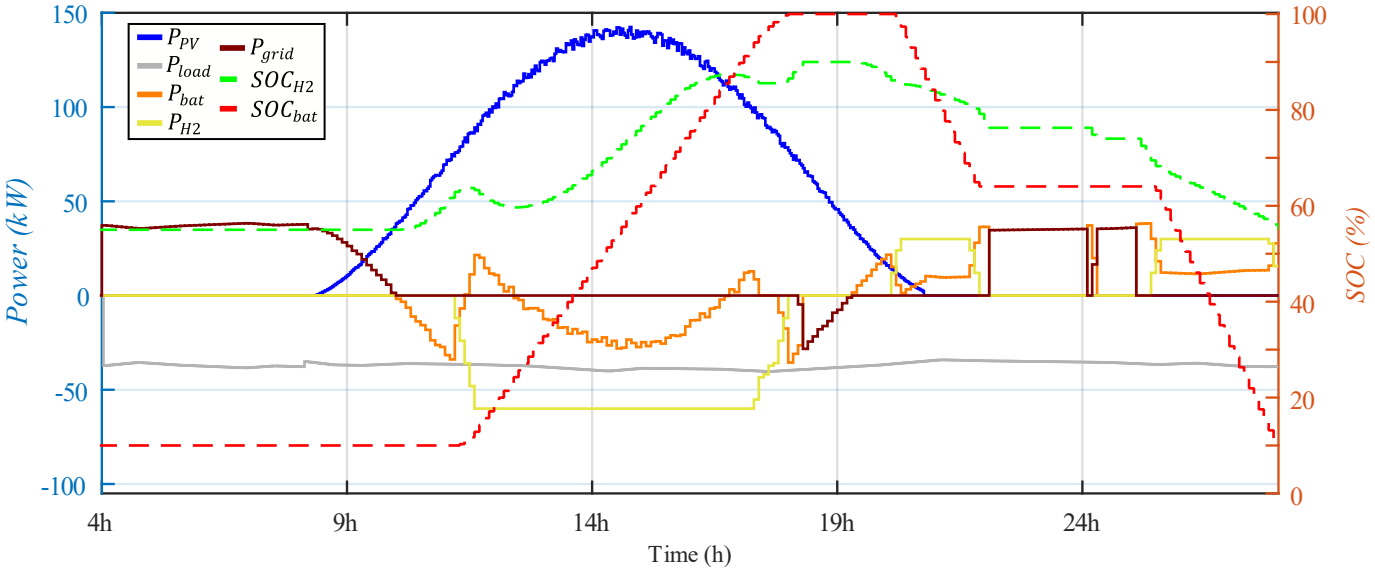

Fig. 3. 15. Power and SOC profiles obtained for scenario 7 and industrial application.

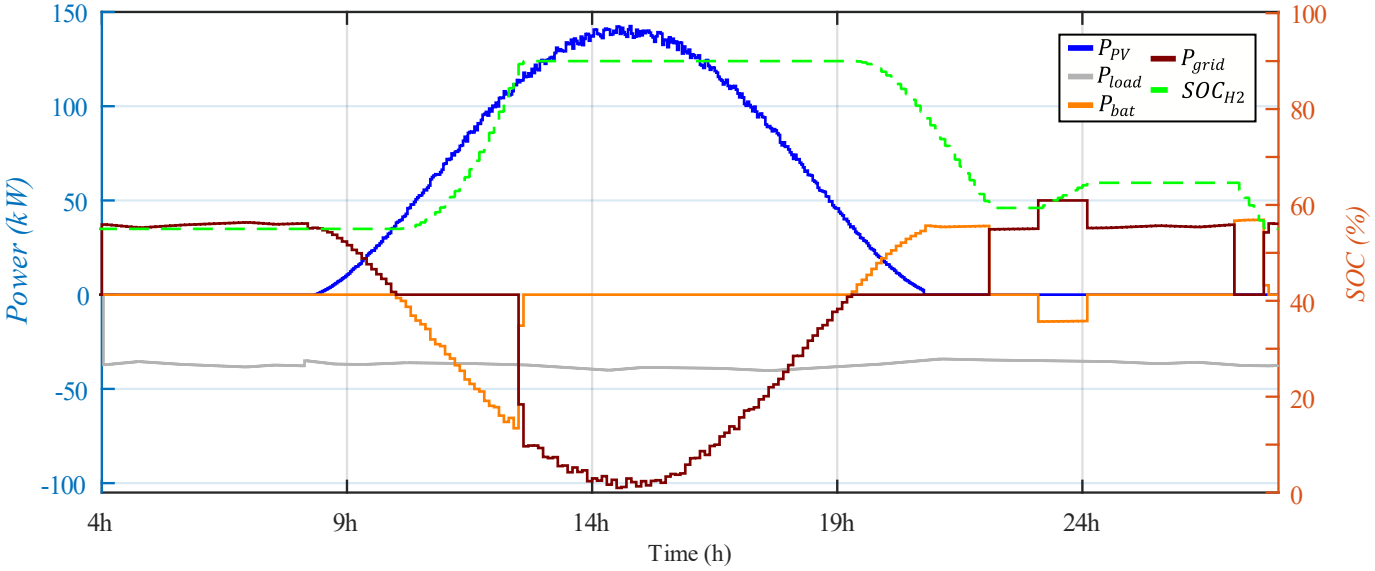

Fig. 3. 16. Power and SOC profiles obtained for scenario 7 and industrial application.

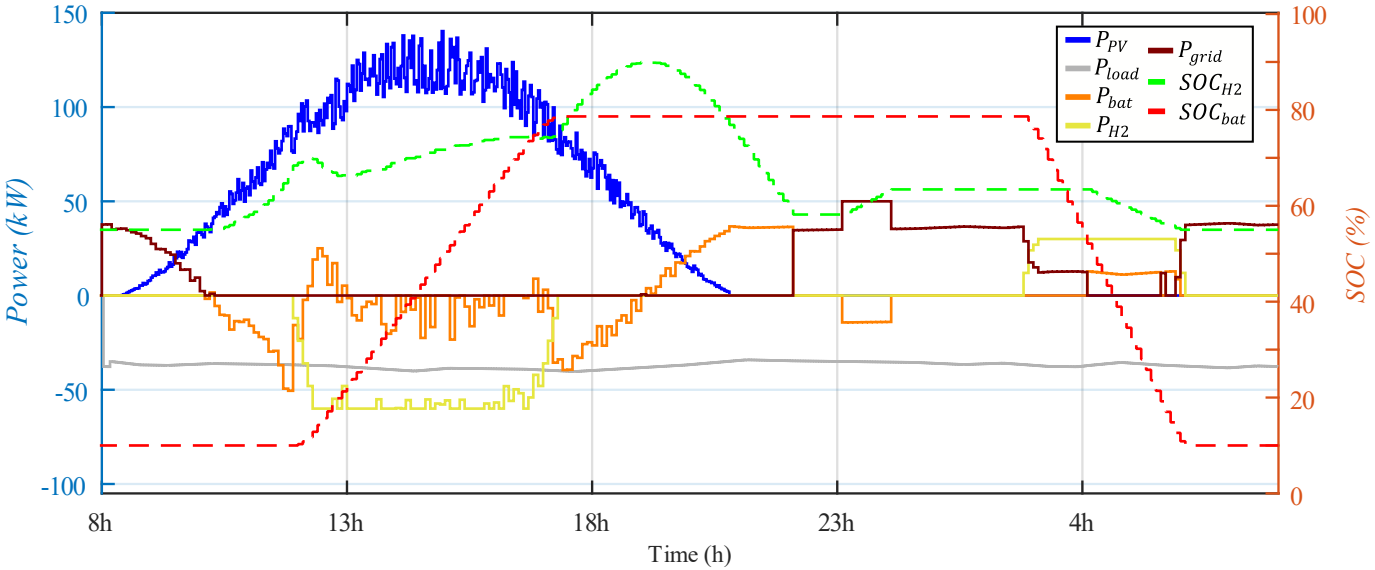

Fig. 3. 17. Power and SOC profiles obtained for scenario 8 and industrial application.

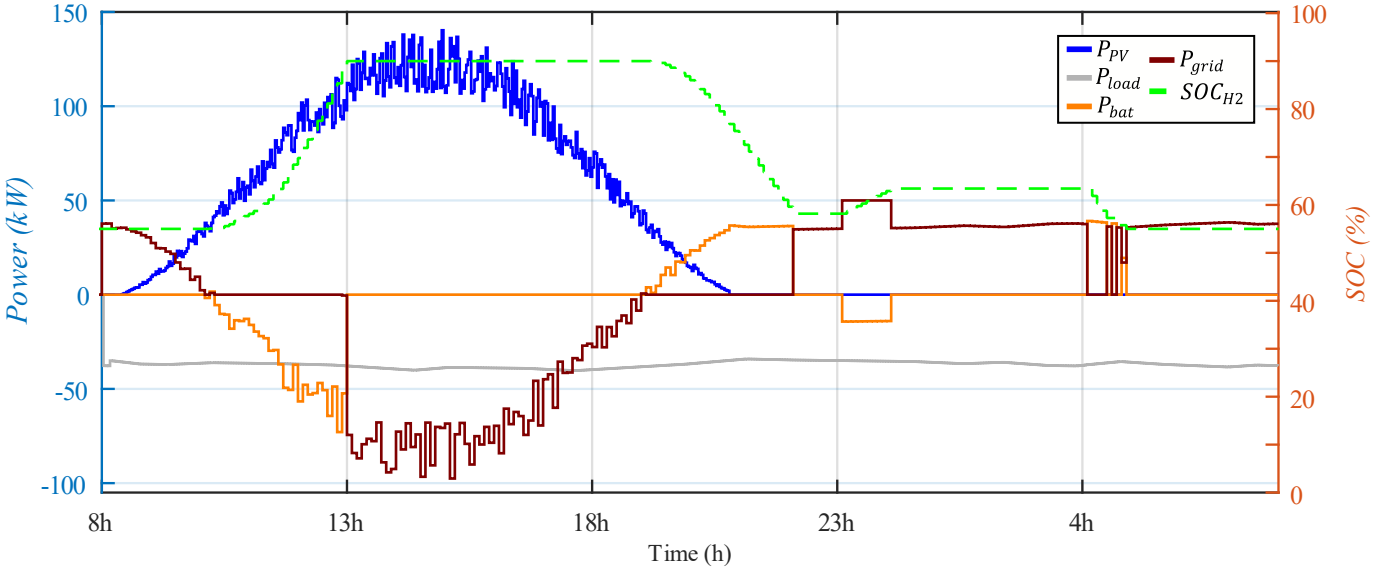

Fig. 3. 18. Power and SOC profiles obtained for scenario 8 and 9 and industrial application.

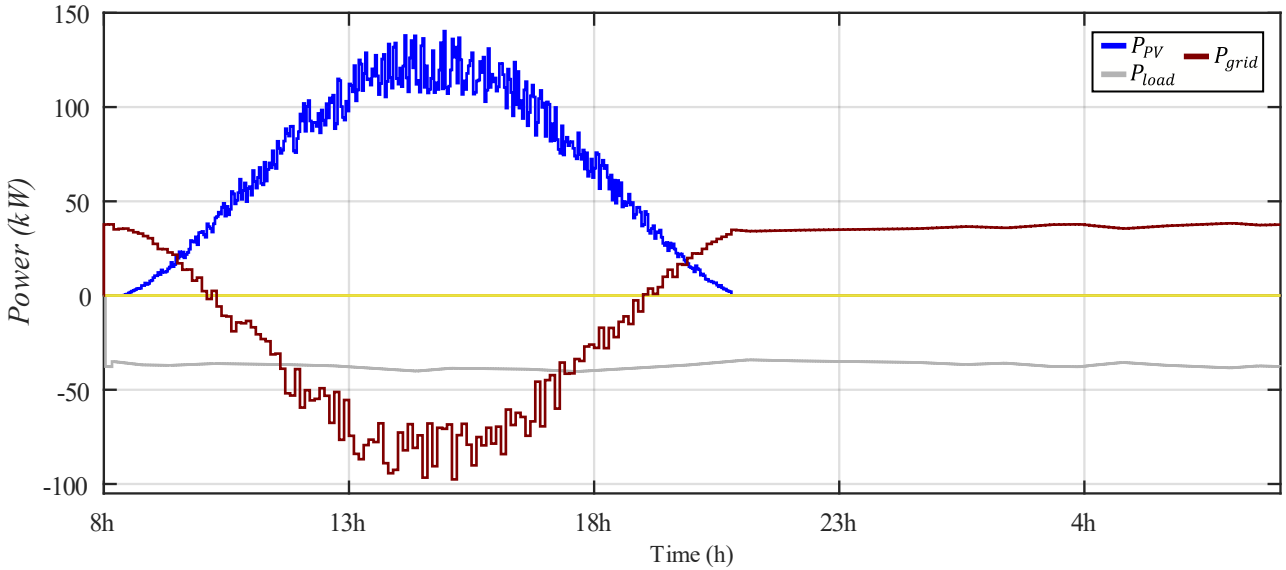

Fig. 3. 19. Power and SOC profiles obtained for scenario 8 and industrial application.

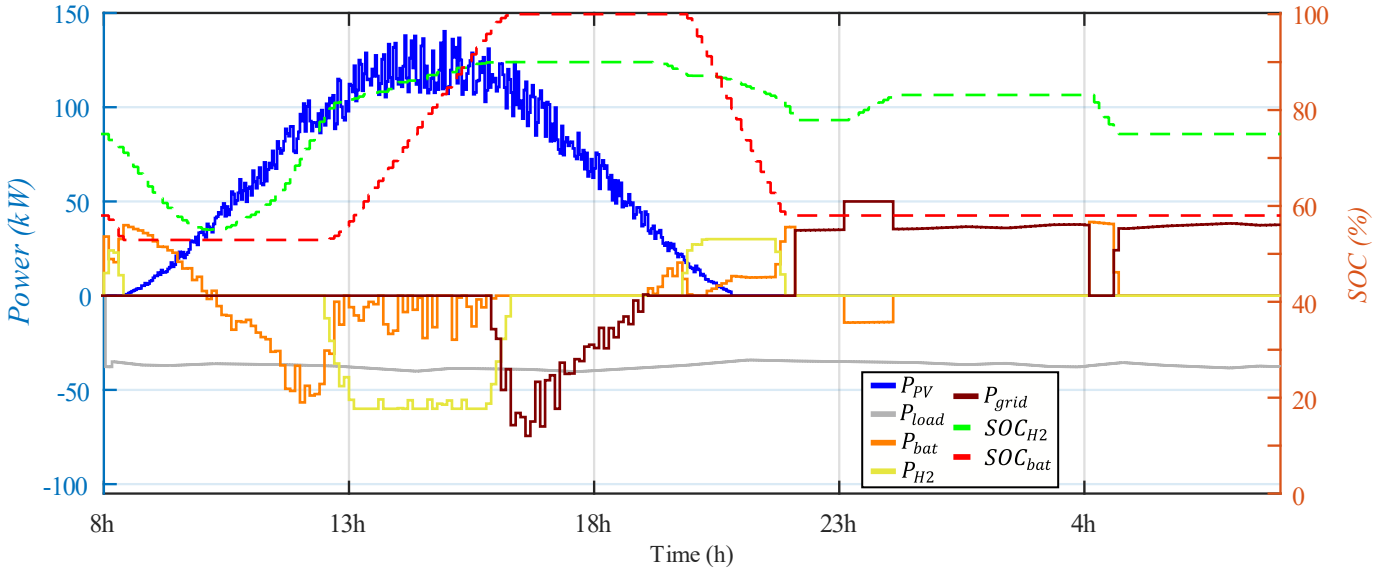

Fig. 3. 20. Power and SOC profiles obtained for scenario 9 and industrial application.

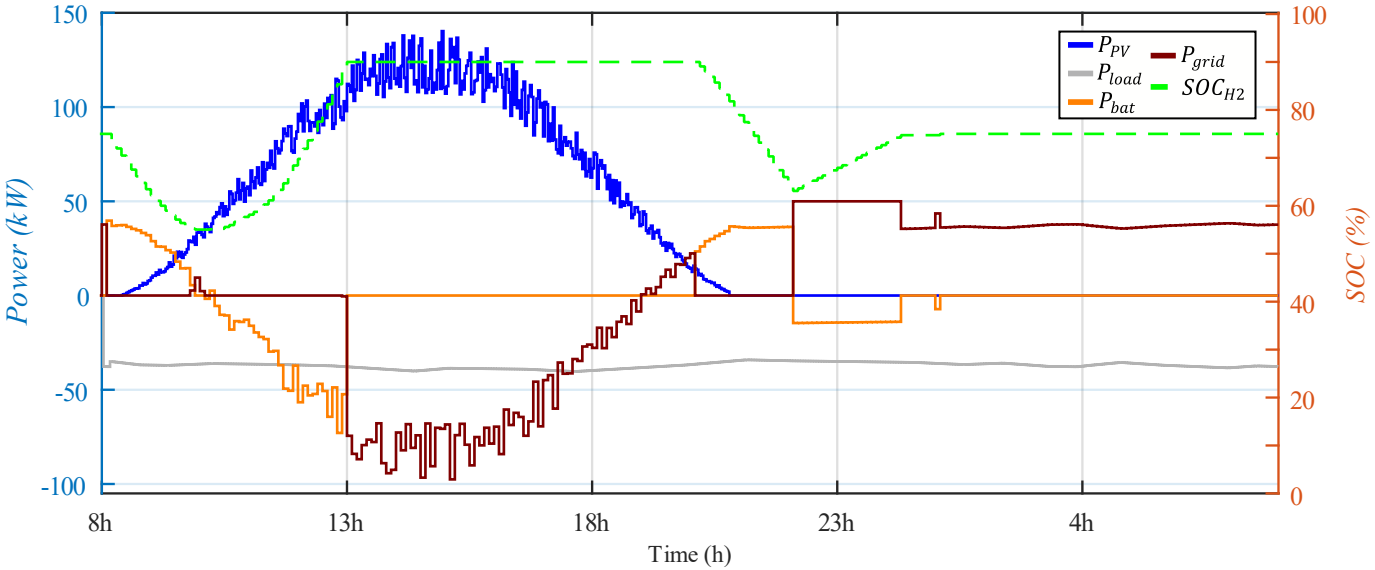

Fig. 3. 21. Power and SOC profiles obtained for scenario 9 and industrial application.

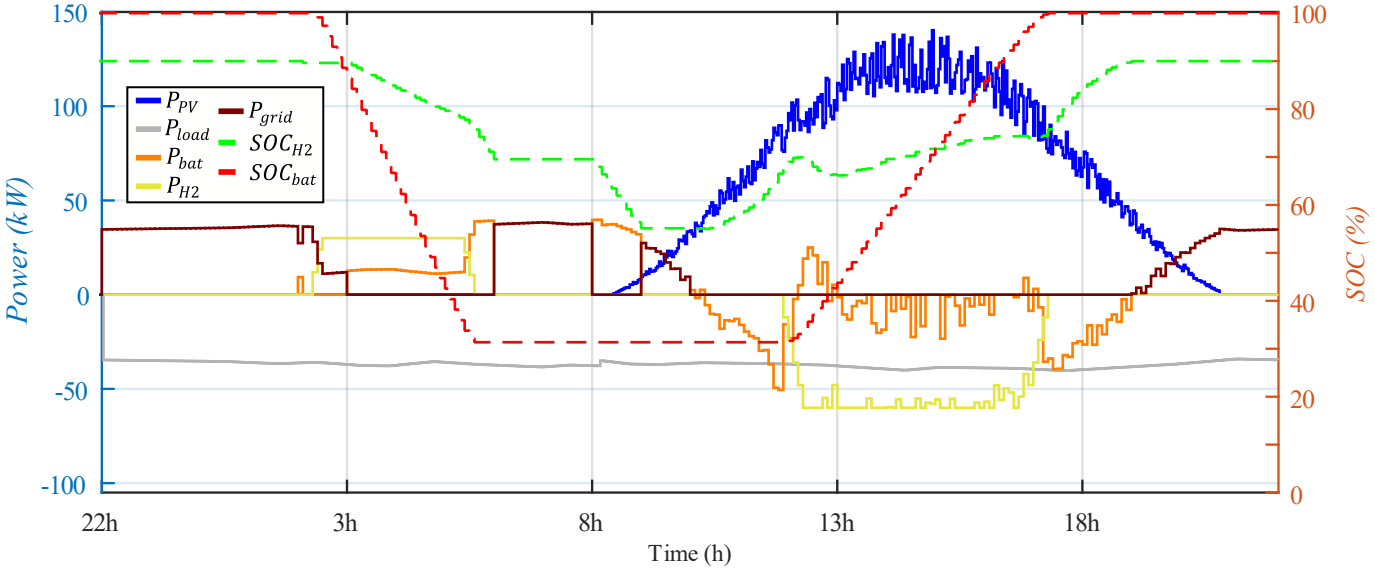

Fig. 3. 22. Power and SOC profiles obtained for scenario 10 and industrial application.

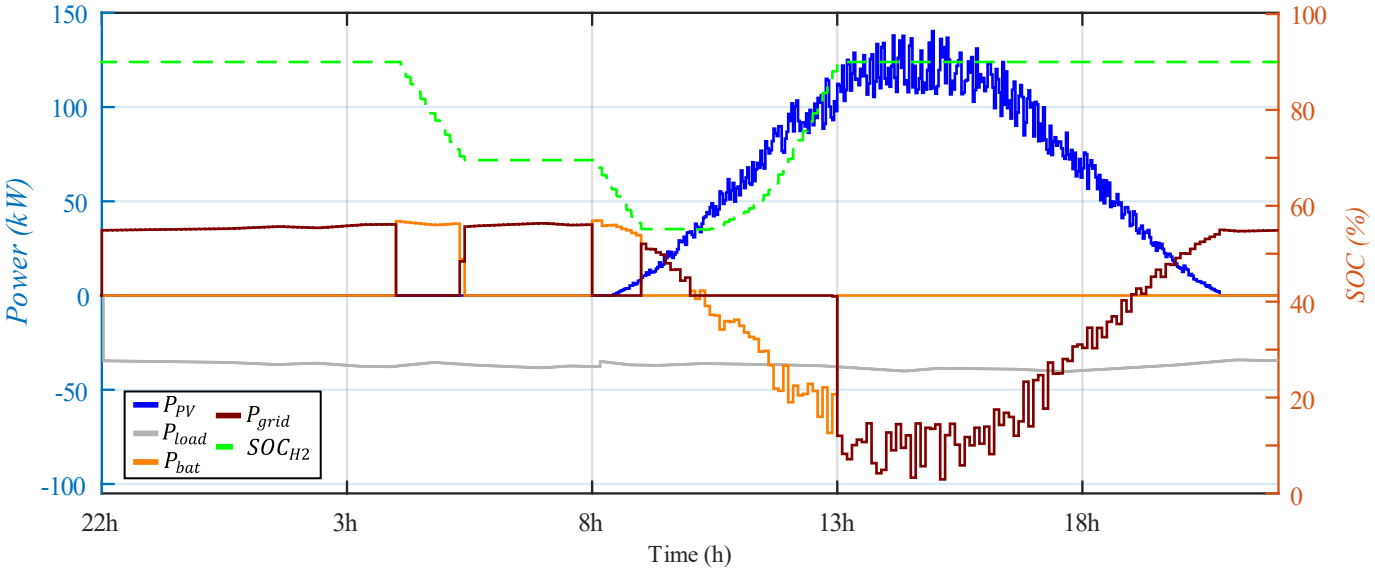

Fig. 3. 23. Power and SOC profiles obtained for scenario 10 and industrial application.

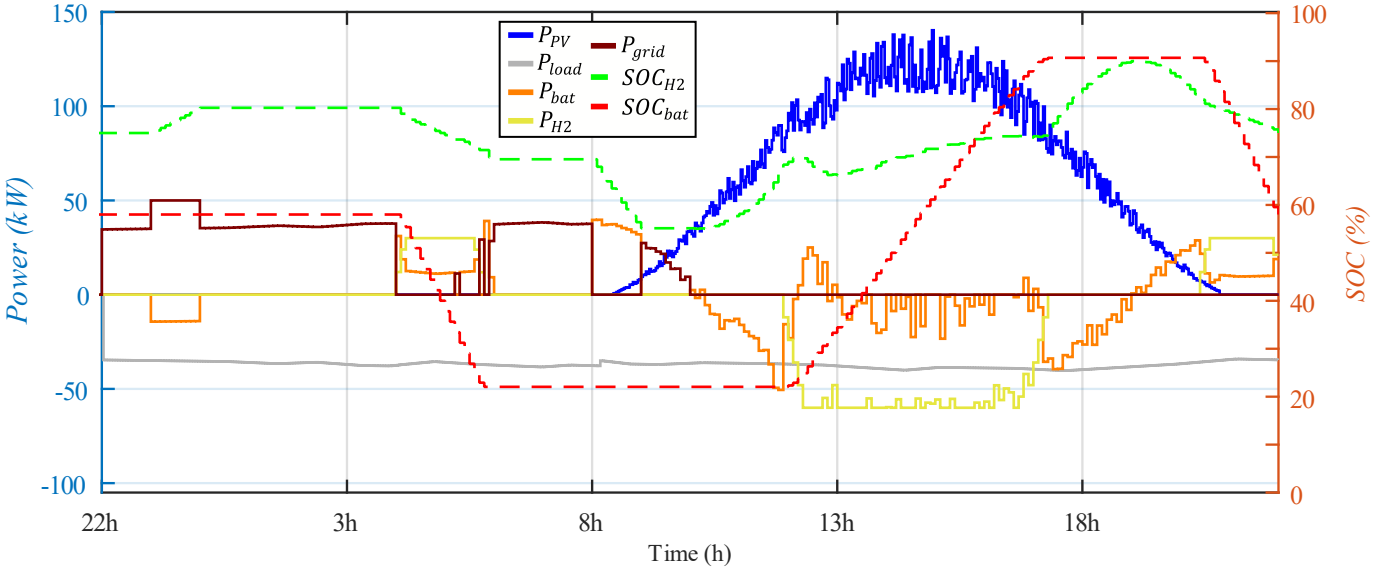

Fig. 3. 24. Power and SOC profiles obtained for scenario 11 and industrial application.

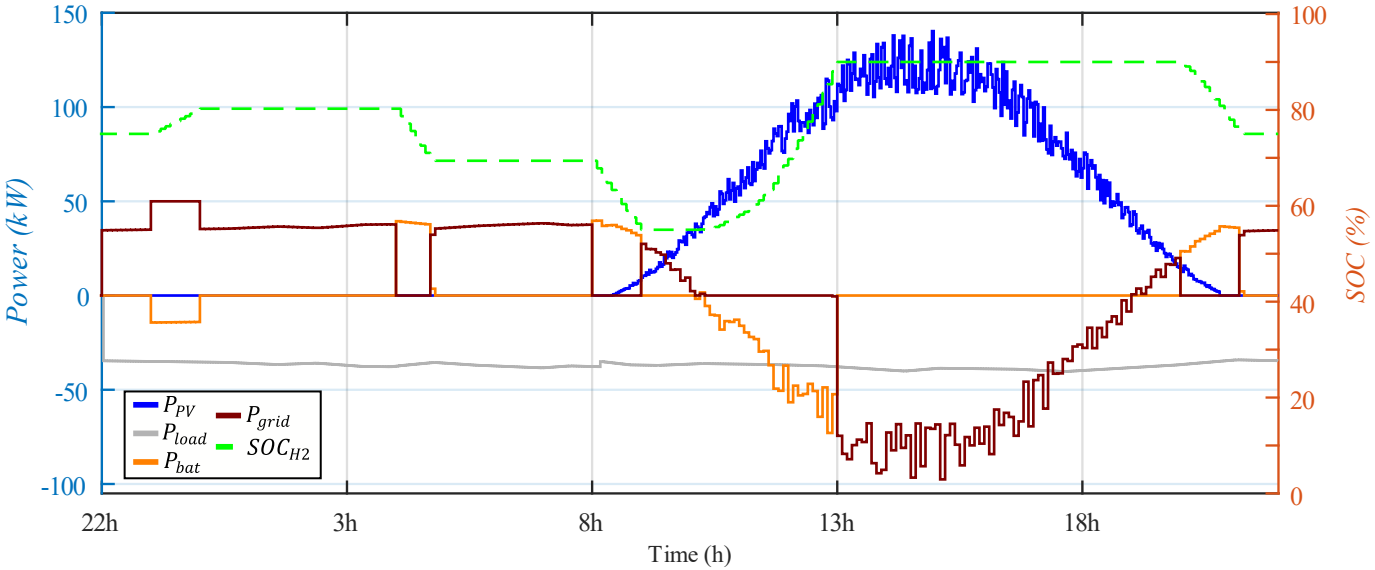

Fig. 3. 25. Power and SOC profiles obtained for scenario 11 and industrial application.

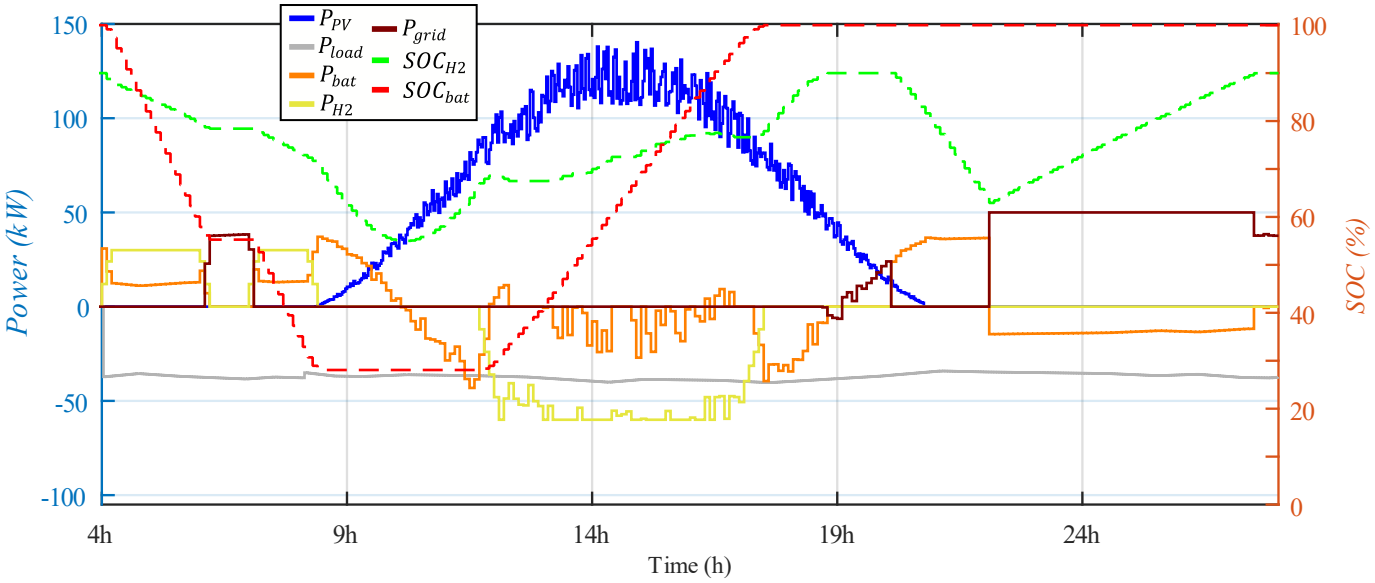

Fig. 3. 26. Power and SOC profiles obtained for scenario 12 and industrial application.

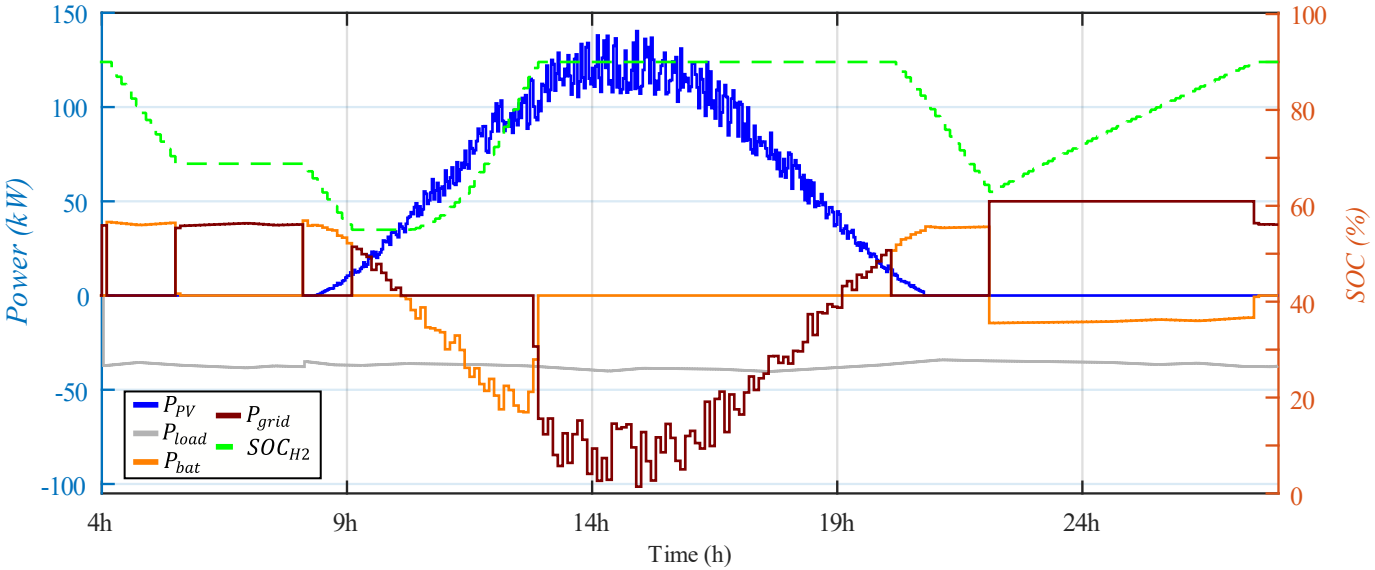

Fig. 3. 27. Power and SOC profiles obtained for scenario 12 and industrial application.

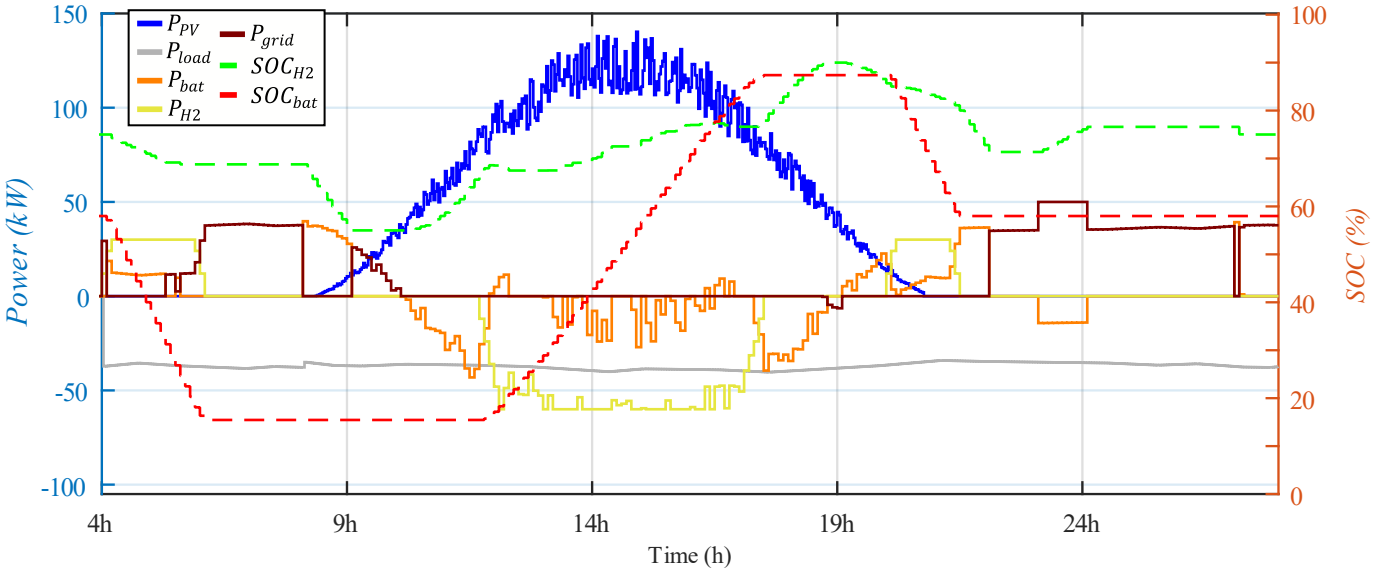

Fig. 3. 28. Power and SOC profiles obtained for scenario 13 and industrial application.

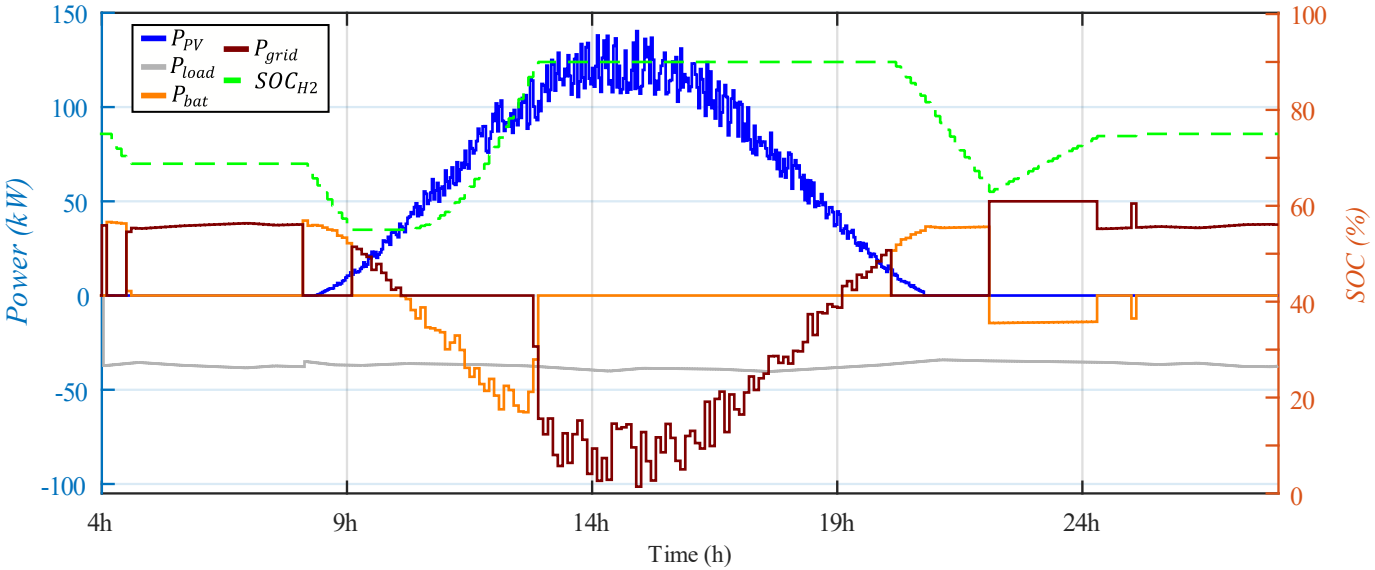

Fig. 3. 29. Power and SOC profiles obtained for scenario 13 and industrial application.

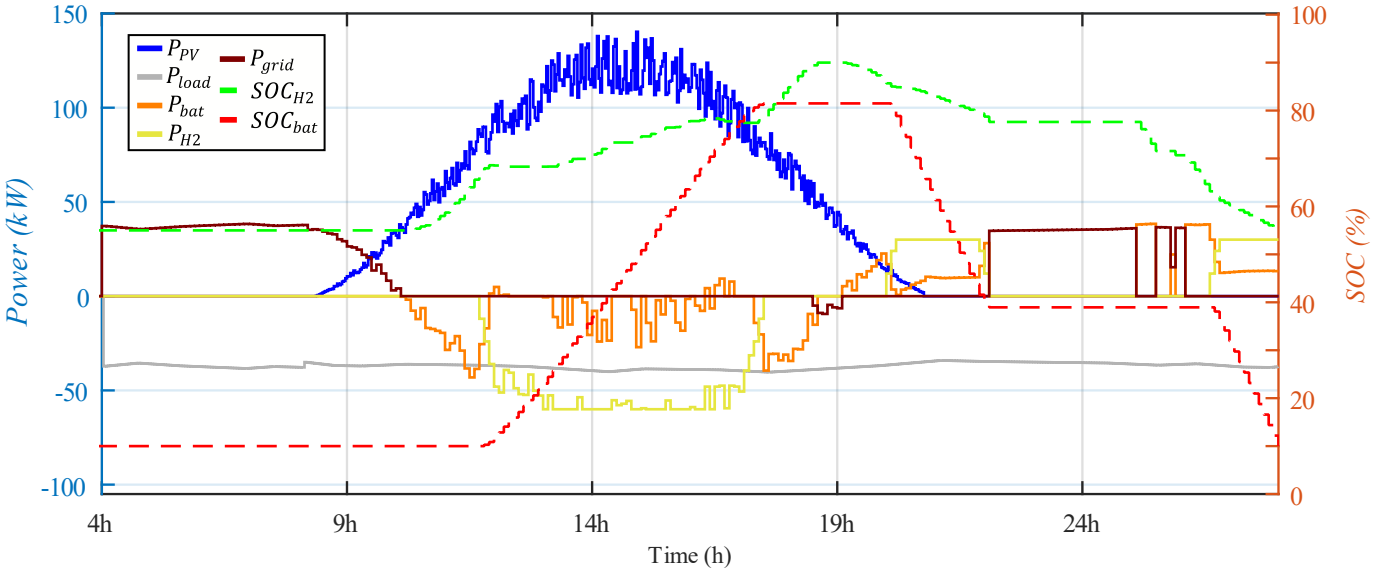

Fig. 3. 30. Power and SOC profiles obtained for scenario 14 and industrial application.

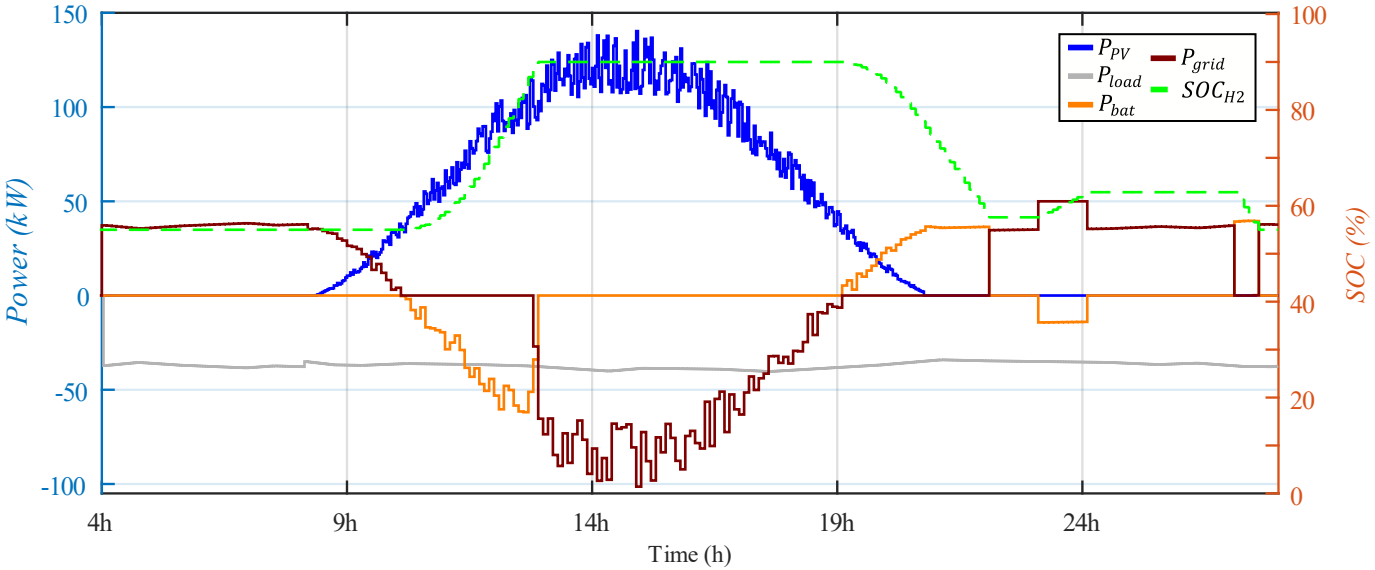

Fig. 3. 31. Power and SOC profiles obtained for scenario 14 and industrial application.

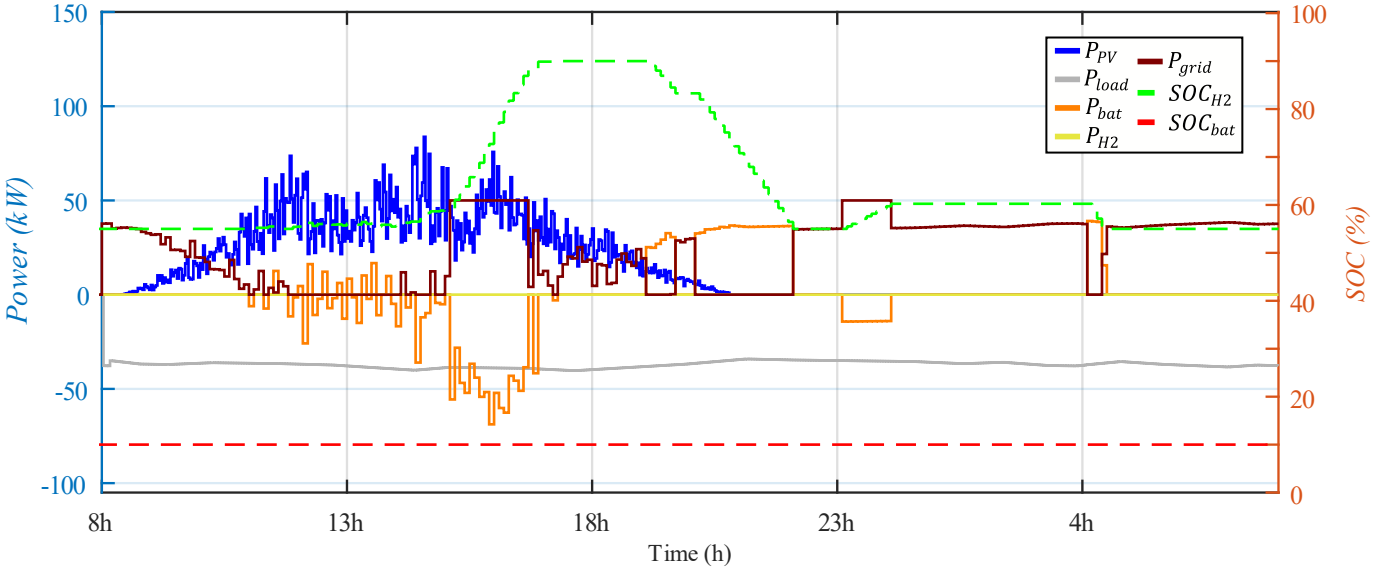

Fig. 3. 32. Power and SOC profiles obtained for scenario 15 and 16 and industrial application.

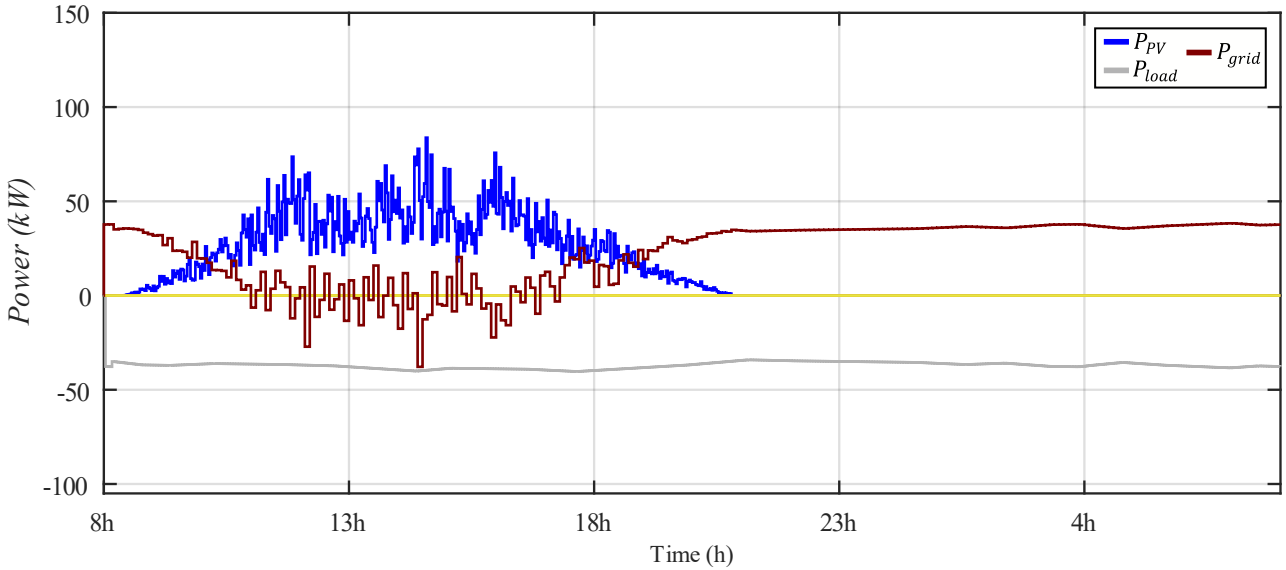

Fig. 3. 33. Power and SOC profiles obtained for scenario 15 and industrial application.

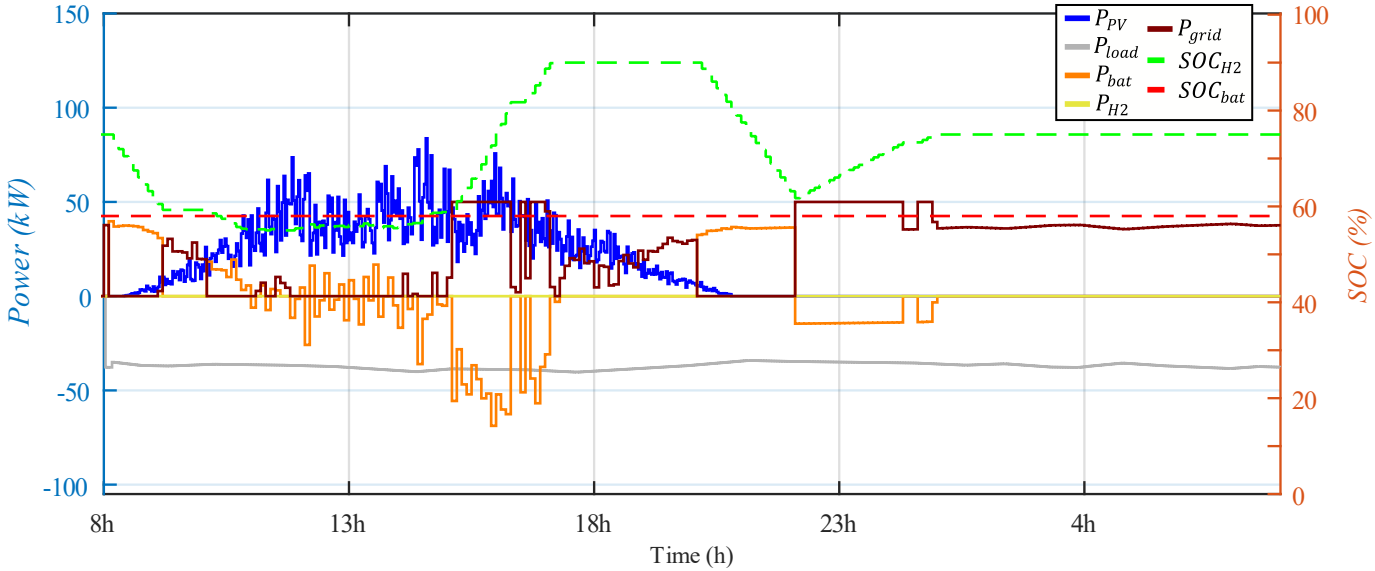

Fig. 3. 34. Power and SOC profiles obtained for scenario 16 and industrial application.

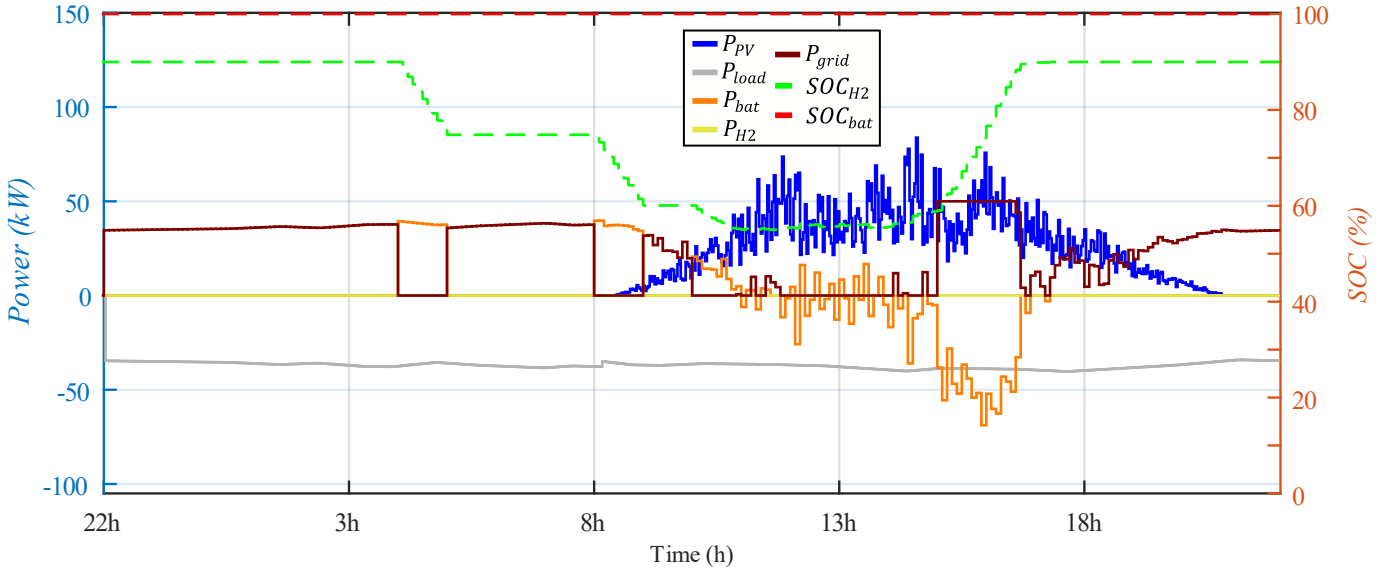

Fig. 3. 35. Power and SOC profiles obtained for scenario 17 and industrial application.

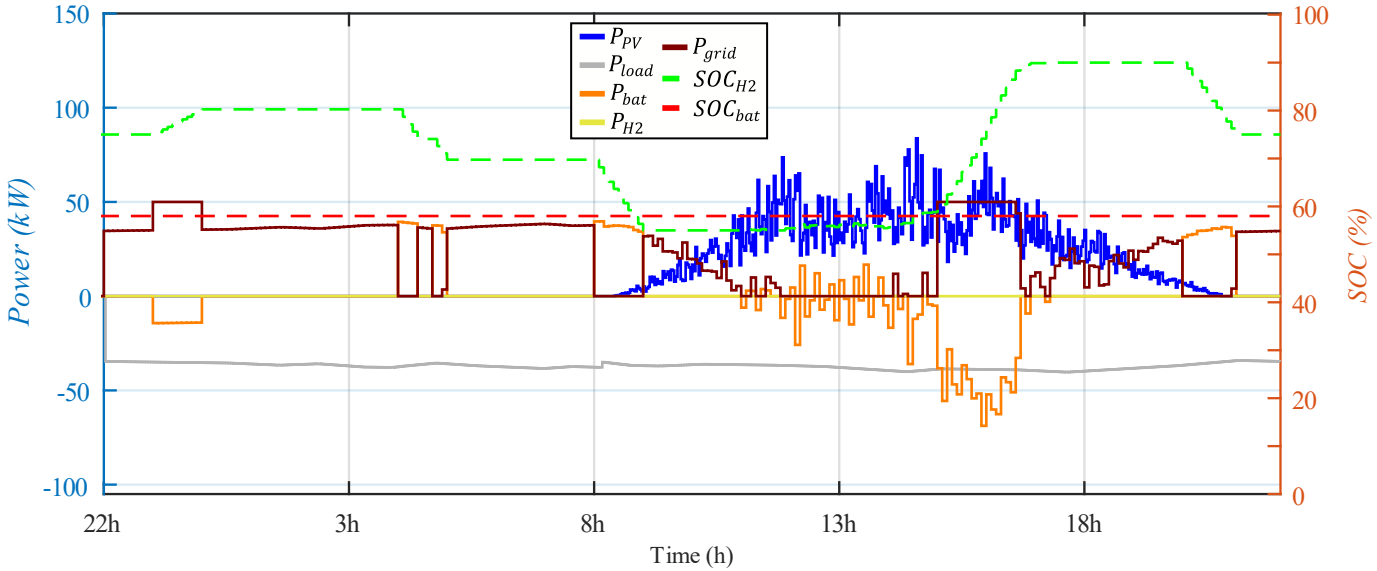

Fig. 3. 36. Power and SOC profiles obtained for scenario 18 and industrial application.

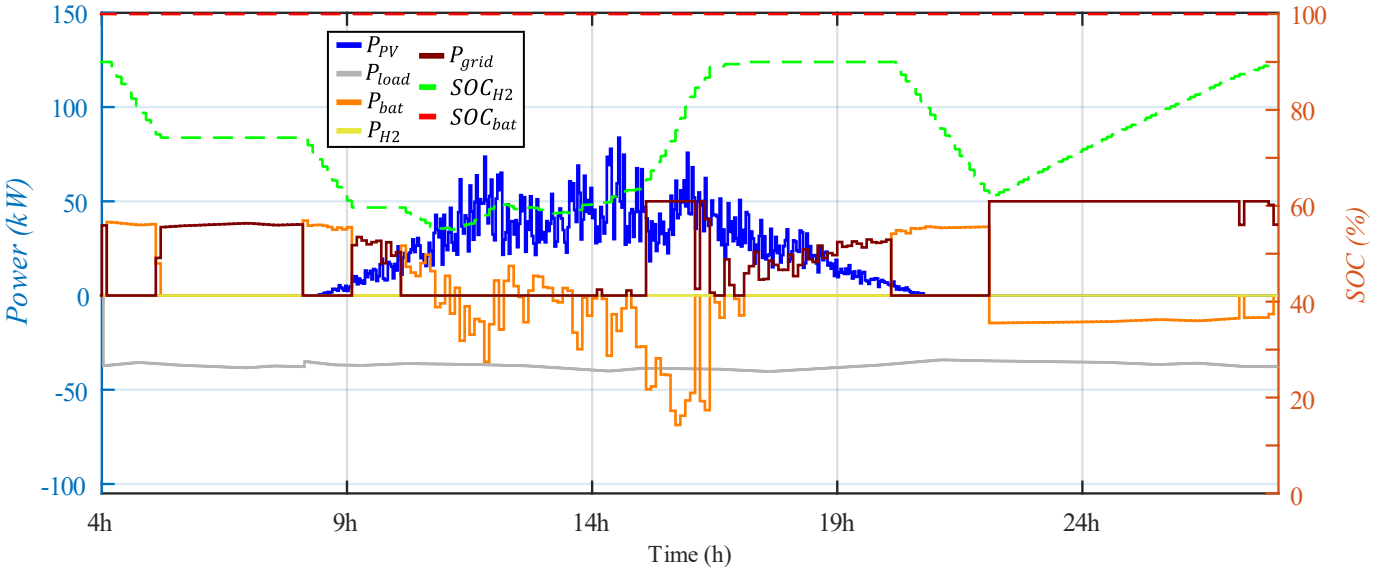

Fig. 3. 37. Power and SOC profiles obtained for scenario 19 and industrial application.

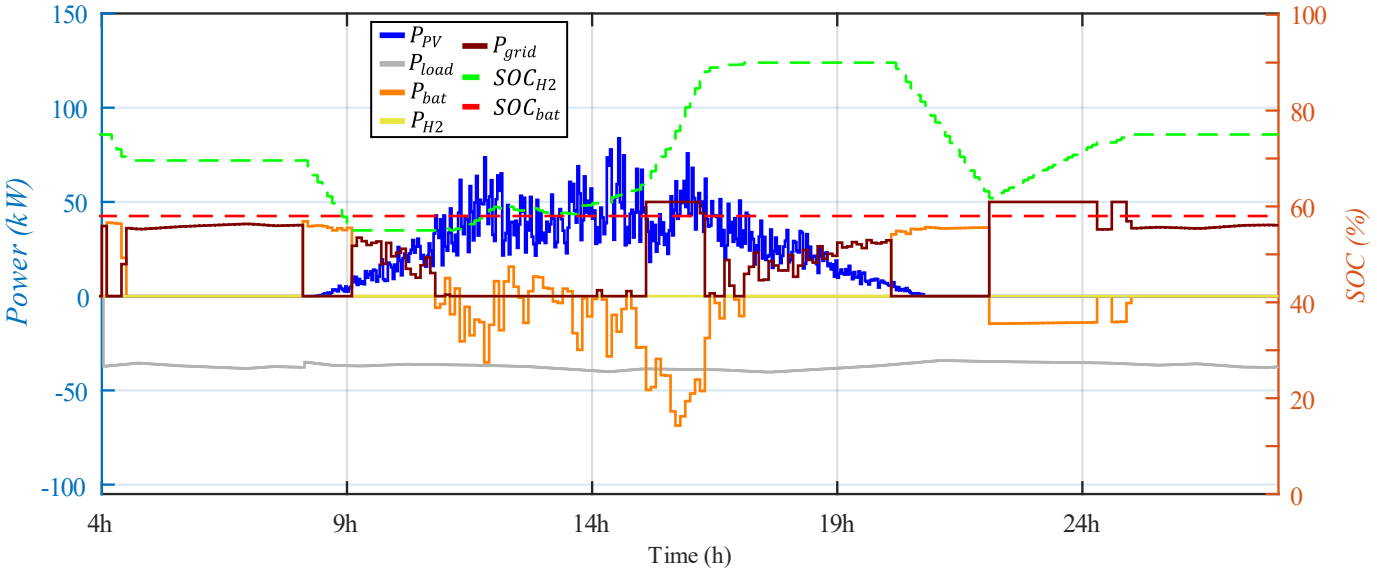

Fig. 3. 38. Power and SOC profiles obtained for scenario 20 and industrial application.

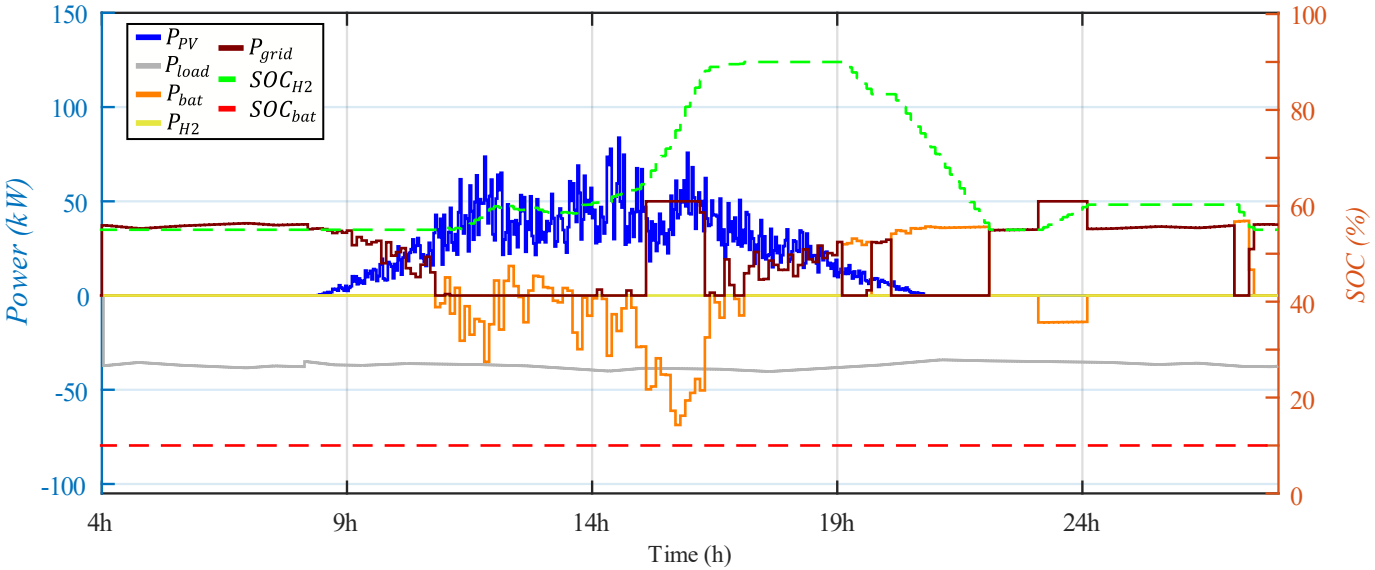

Fig. 3. 39. Power and SOC profiles obtained for scenario 21 and industrial application.

Table 3. Results obtained in the microgrid architecture for industrial application (case 3, Fig. 1). $PH = 24\ h.\ T_s = 0.1\ h. (360\ sec.)$.

Scenario			Cost							Computational cost[2] (sec.)
Number	Day	Initial conditions	$Cost_{MPC}$ (€)	$Cost_{MPC}/Cost_{MEG}$ (%)	$Cost_{MPC}^{BSS}$ (€)	$Cost_{MPC}^{BSS}/Cost_{MEG}$ (%)	$Cost_{ren}$ (€)	$Cost_{ren}/Cost_{MEG}$ (%)	$Cost_{MEG}$ (€)	
1	Sunny	Starts at 8h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 10\%$	111.64 Fig. 3. 1	33.49	120.51 Fig. 3. 2	36.15	153.32 Fig. 3. 3	45.99	333.35 Fig. 3. 4	6.47 ($Cost_{MPC}$) 0.57 ($Cost_{MPC}^{BSS}$)
2	Sunny	Starts at 8h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 58\%$	115.40 Fig. 3. 5	34.62	120.08 Fig. 3. 6	36.02	153.32 Fig. 3. 3	45.99	333.35 Fig. 3. 4	186.74 ($Cost_{MPC}$) 0.56 ($Cost_{MPC}^{BSS}$)
3	Sunny	Starts at 22h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$	117.10 Fig. 3. 7	35.13	125.70 Fig. 3. 8	37.71	153.32	45.99	333.35	5.83 ($Cost_{MPC}$) 0.55 ($Cost_{MPC}^{BSS}$)
4	Sunny	Starts at 22h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 58\%$	111.56 Fig. 3. 9	33.47	121.87 Fig. 3. 10	36.56	153.32	45.99	333.35	51.71 ($Cost_{MPC}$) 0.54 ($Cost_{MPC}^{BSS}$)
5	Sunny	Starts at 4h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$	114.29 Fig. 3. 11	34.29	122.01 Fig. 3. 12	36.60	153.32	45.99	333.35	5.84 ($Cost_{MPC}$) 0.56 ($Cost_{MPC}^{BSS}$)
6	Sunny	Starts at 4h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 58\%$	110.54 Fig. 3. 13	33.16	119.79 Fig. 3. 14	35.94	153.32	45.99	333.35	7.72 ($Cost_{MPC}$) 0.54 ($Cost_{MPC}^{BSS}$)
7	Sunny	Starts at 4h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 10\%$	112.52 Fig. 3. 15	33.75	120.46 Fig. 3. 16	36.14	153.32	45.99	333.35	4.43 ($Cost_{MPC}$) 0.57 ($Cost_{MPC}^{BSS}$)
8	Sunny with clouds	Starts at 8h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 10\%$	124.03 Fig. 3. 17	37.21	130.75 Fig. 3. 18	39.22	163.76 Fig. 3. 19	49.13	333.35 Fig. 3. 4	5.76 ($Cost_{MPC}$) 0.55 ($Cost_{MPC}^{BSS}$)

[2] CPU processor Intel Core i7, 3.2 GHz with 16 GB RAM.

9	Sunny with clouds	Starts at 8h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 58\%$	125.43 Fig. 3. 20	37.63	130.40 Fig. 3. 21	39.12	163.76 Fig. 3. 19	49.13	333.35 Fig. 3. 4	59.29 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.54 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
10	Sunny with clouds	Starts at 22h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 90\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 100\%$	129.65 Fig. 3. 22	38.89	136.14 Fig. 3. 23	40.84	163.76	49.13	333.35	6.36 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.58 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
11	Sunny with clouds	Starts at 22h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 58\%$	122.97 Fig. 3. 24	36.89	132.30 Fig. 3. 25	39.69	163.76	49.13	333.35	8.25 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.55 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
12	Sunny with clouds	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 90\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 100\%$	125.32 Fig. 3. 26	37.59	131.36 Fig. 3. 27	39.41	163.76	49.13	333.35	14.26 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.58 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
13	Sunny with clouds	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 58\%$	121.57 Fig. 3. 28	36.47	129.12 Fig. 3. 29	38.73	163.76	49.13	333.35	14.31 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.56 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
14	Sunny with clouds	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 10\%$	123.28 Fig. 3. 30	36.98	129.66 Fig. 3. 31	38.90	163.76	49.13	333.35	0.88 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.56 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
15	Cloudy	Starts at 8h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 10\%$	206.68 Fig. 3. 32	62.00	206.68 Fig. 3. 32	62.00	224.27 Fig. 3. 33	67.28	333.35 Fig. 3. 4	14.66 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.98 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
16	Cloudy	Starts at 8h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 58\%$	206.39 Fig. 3. 34	61.91	206.39 Fig. 3. 34	61.91	224.27 Fig. 3. 33	67.28	333.35 Fig. 3. 4	0.94 ($\mathrm{Cost}_{\mathrm{MPC}}$) 1.09 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
17	Cloudy	Starts at 22h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 90\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 100\%$	212.71 Fig. 3. 35	63.81	212.71 Fig. 3. 35	63.81	224.27	67.28	333.35	0.92 ($\mathrm{Cost}_{\mathrm{MPC}}$) 1.30 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
18	Cloudy	Starts at 22h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 58\%$	208.85 Fig. 3. 36	62.65	208.85 Fig. 3. 36	62.65	224.27	67.28	333.35	0.93 ($\mathrm{Cost}_{\mathrm{MPC}}$) 1.18 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)

19	Cloudy	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 90\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 100\%$	202.65 Fig. 3. 37	60.79	202.65 Fig. 3. 37	60.79	224.27	67.28	333.35	0.91 ($\mathrm{Cost}_{\mathrm{MPC}}$) 1.11 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
20	Cloudy	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 75\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 58\%$	200.34 Fig. 3. 38	60.10	200.34 Fig. 3. 38	60.10	224.27	67.28	333.35	0.85 ($\mathrm{Cost}_{\mathrm{MPC}}$) 1.21 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)
21	Cloudy	Starts at 4h $\mathrm{SOC}_{\mathrm{bat}}^{\mathrm{ini}} = 55\%$ $\mathrm{SOC}_{\mathrm{H2}}^{\mathrm{ini}} = 10\%$	200.73 Fig. 3. 39	60.22	200.73 Fig. 3. 39	60.22	224.27	67.28	333.35	0.84 ($\mathrm{Cost}_{\mathrm{MPC}}$) 0.99 ($\mathrm{Cost}_{\mathrm{MPC}}^{\mathrm{BSS}}$)

4. Microgrid architecture for community application (case 4, Fig. 1).

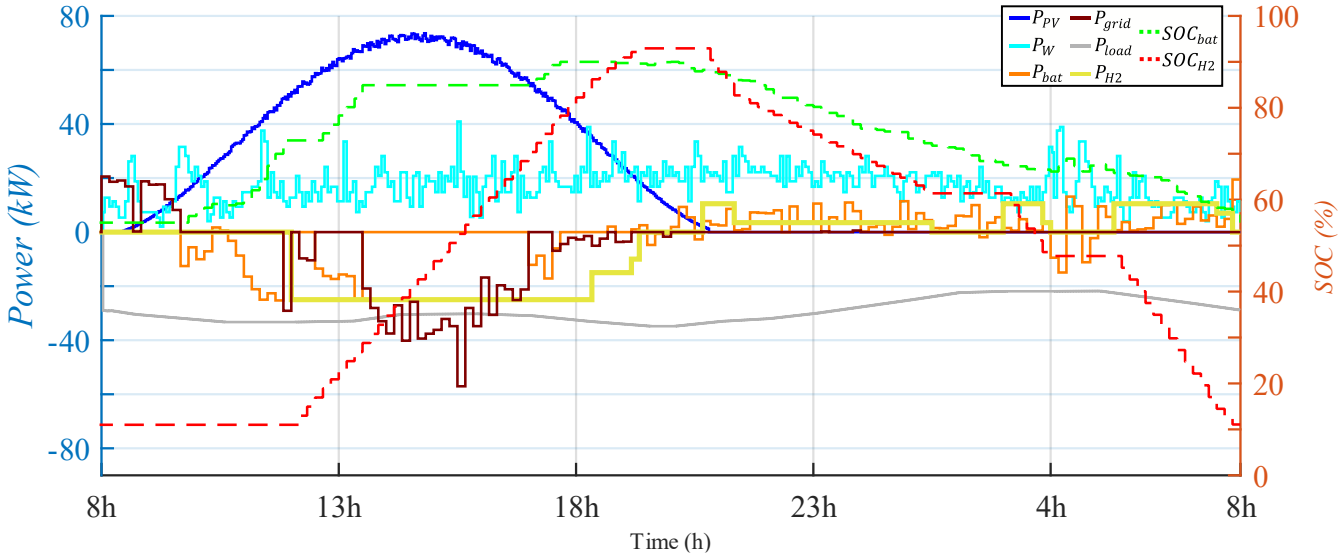

Fig. 4. 1. Power and SOC profiles obtained for scenario 1 and community application.

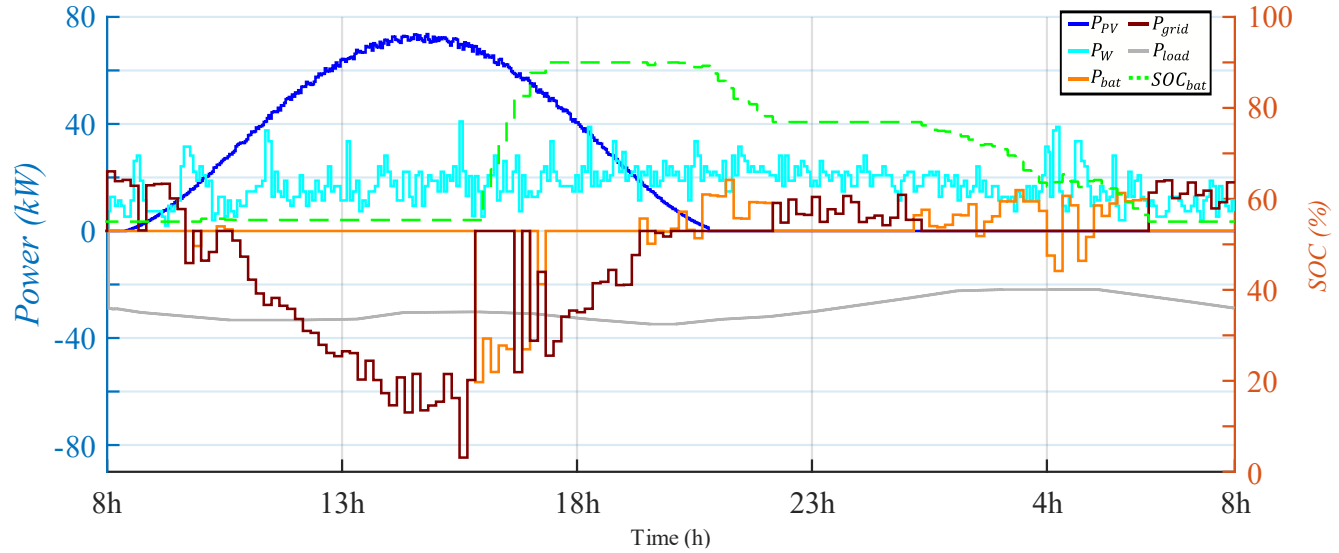

Fig. 4. 2. Power and SOC profiles obtained for scenario 1 and community application.

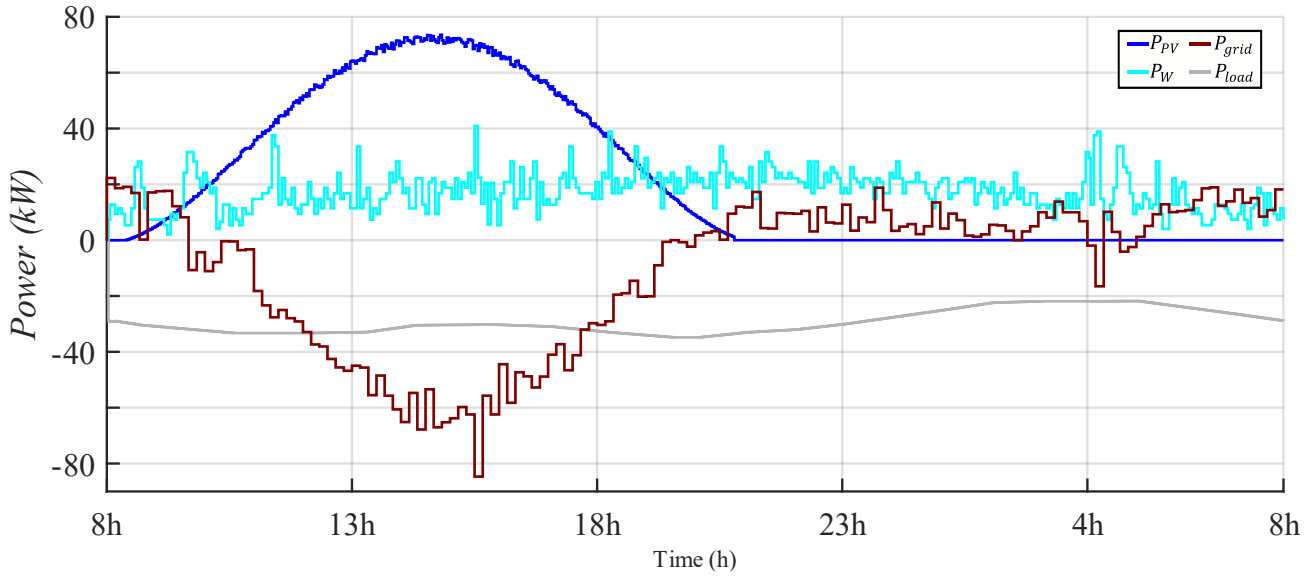

Fig. 4. 3. Power and SOC profiles obtained for scenario 1 and 4 and community application.

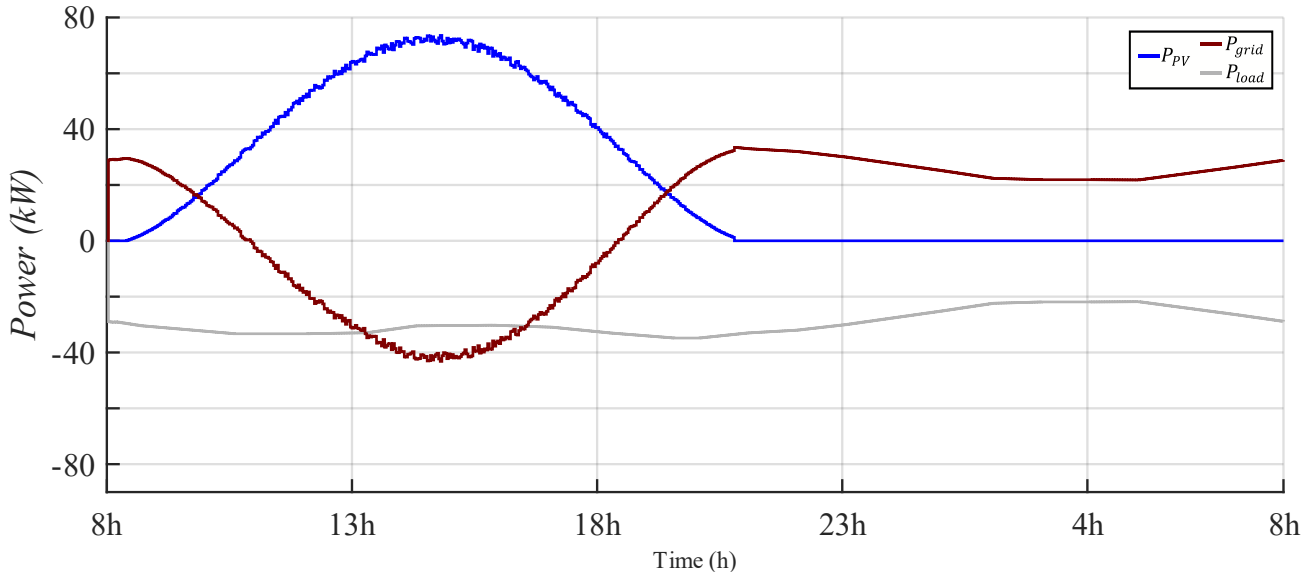

Fig. 4. 4. Power and SOC profiles obtained for scenario 1, 4 and 5 and community application.

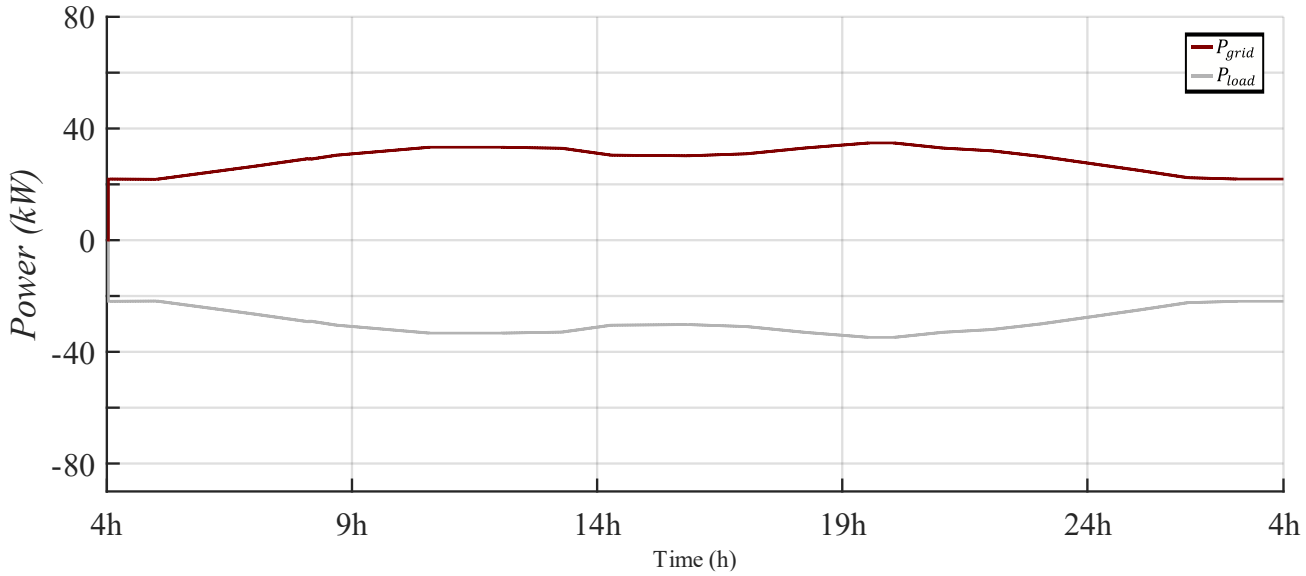

Fig. 4. 5. Power and SOC profiles obtained for scenario 1, 2, 3, 4, 5, 17 and 18 and community application.

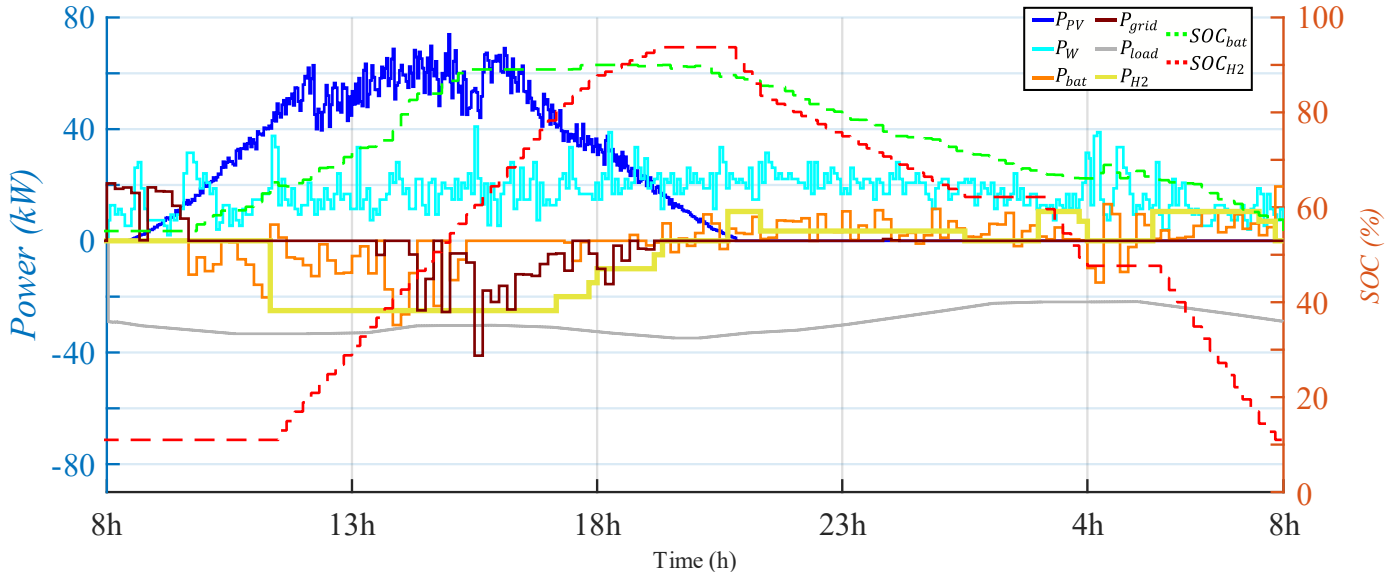

Fig. 4. 6. Power and SOC profiles obtained for scenario 2 and community application.

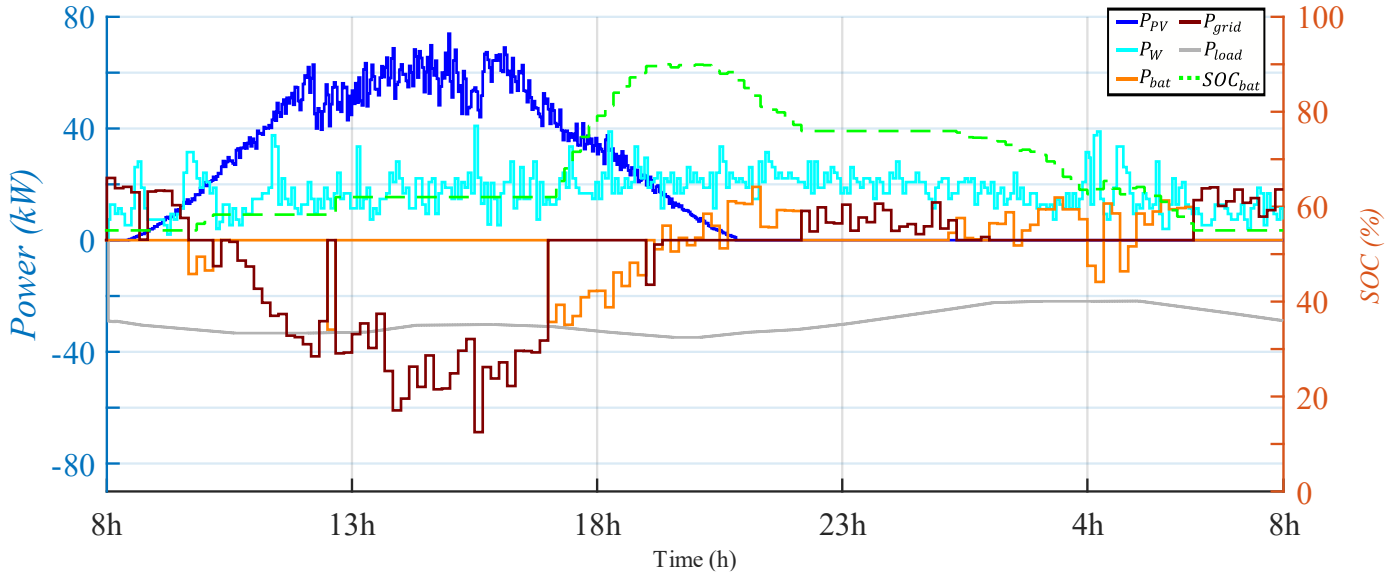

Fig. 4. 7. Power and SOC profiles obtained for scenario 2 and community application.

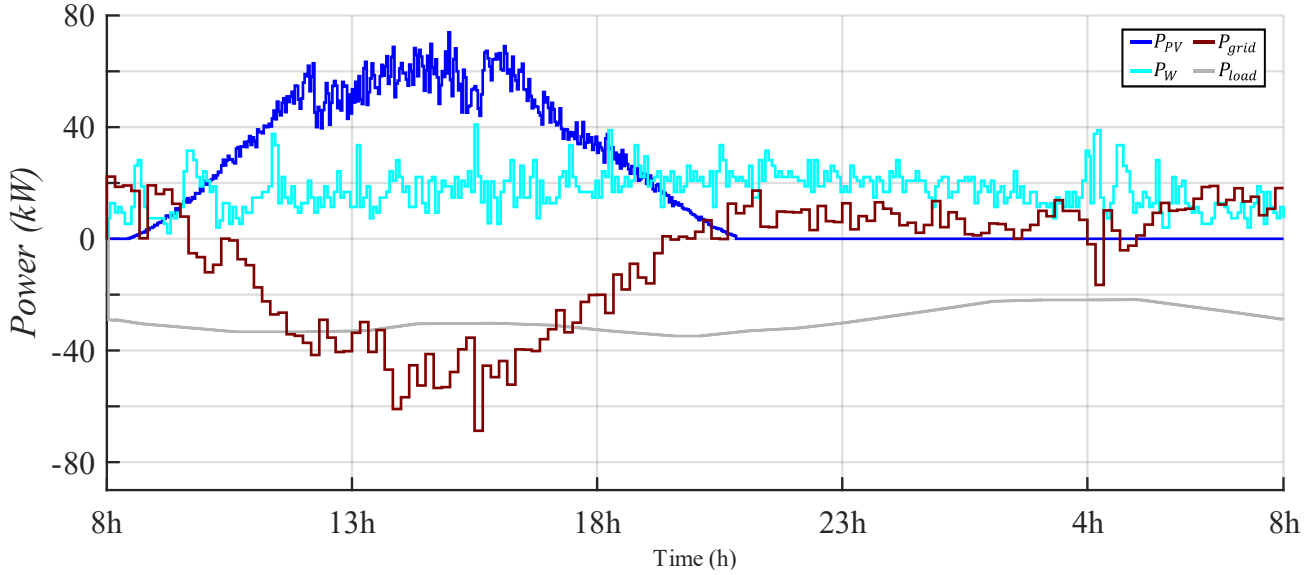

Fig. 4. 8. Power and SOC profiles obtained for scenario 2 and 3 and community application.

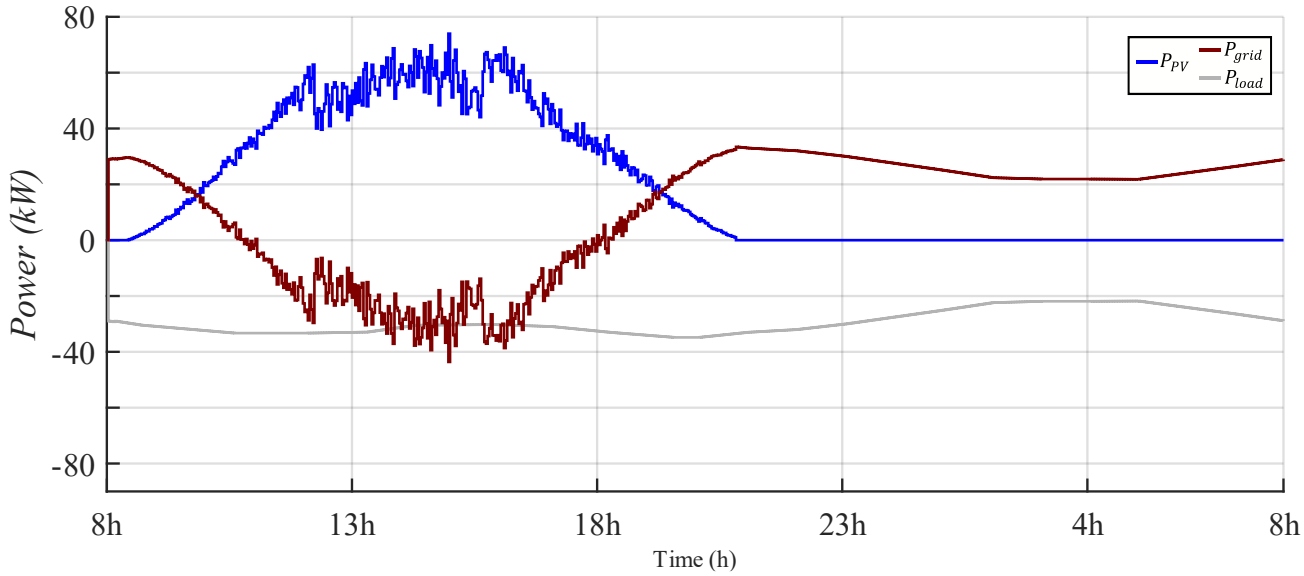

Fig. 4. 9. Power and SOC profiles obtained for scenario 2 and 3 and community application.

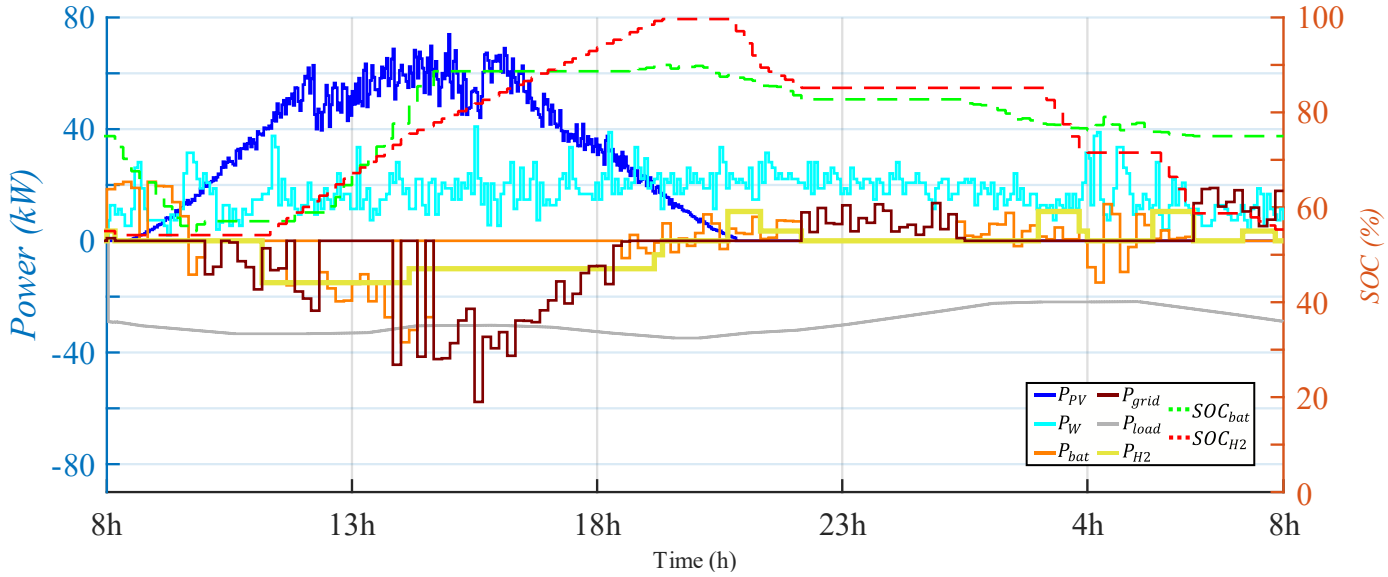

Fig. 4. 10. Power and SOC profiles obtained for scenario 3 and community application.

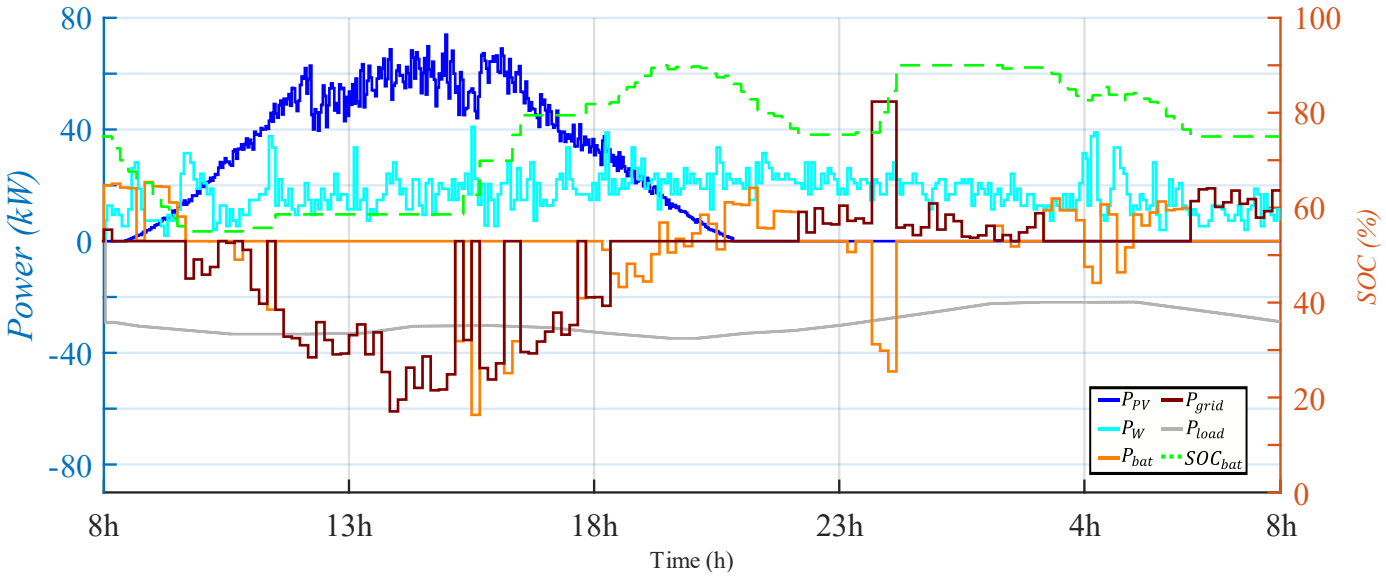

Fig. 4. 11. Power and SOC profiles obtained for scenario 3 and community application.

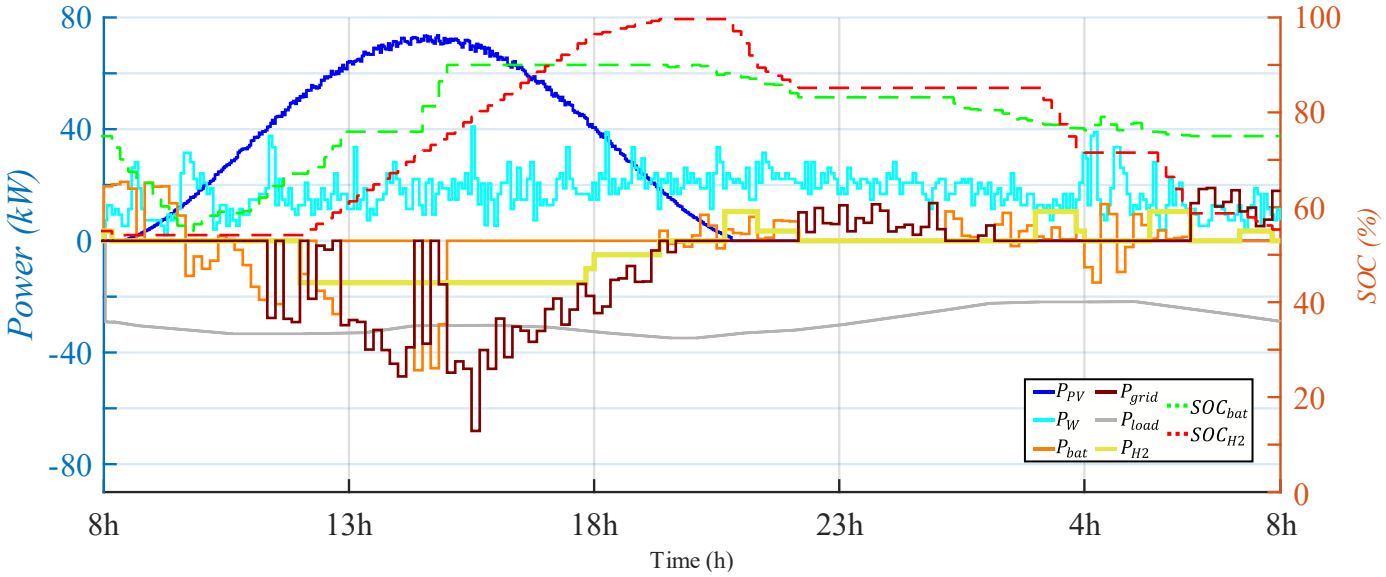

Fig. 4. 12. Power and SOC profiles obtained for scenario 4 and community application.

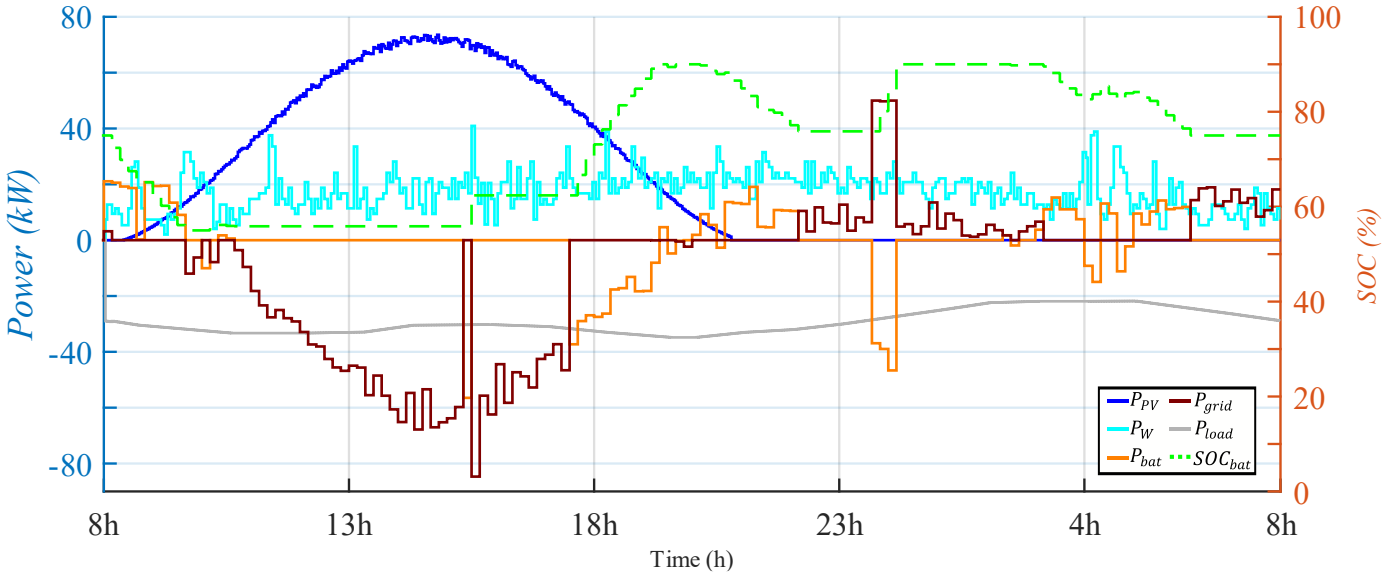

Fig. 4. 13. Power and SOC profiles obtained for scenario 4 and community application.

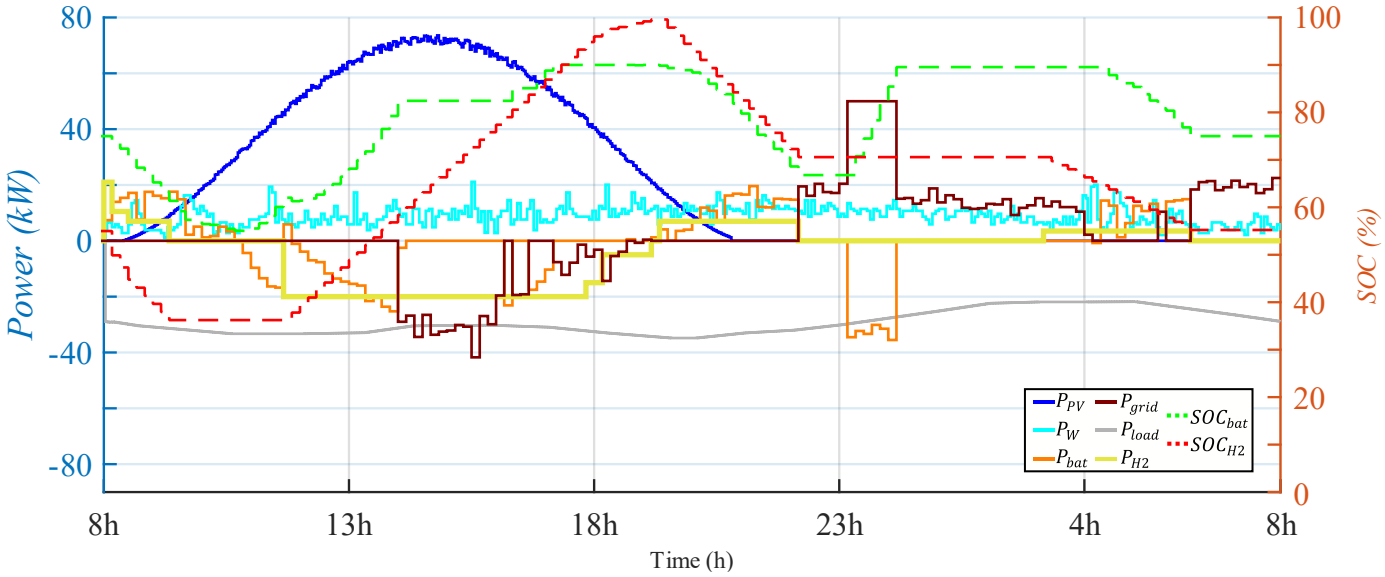

Fig. 4. 14. Power and SOC profiles obtained for scenario 5 and community application.

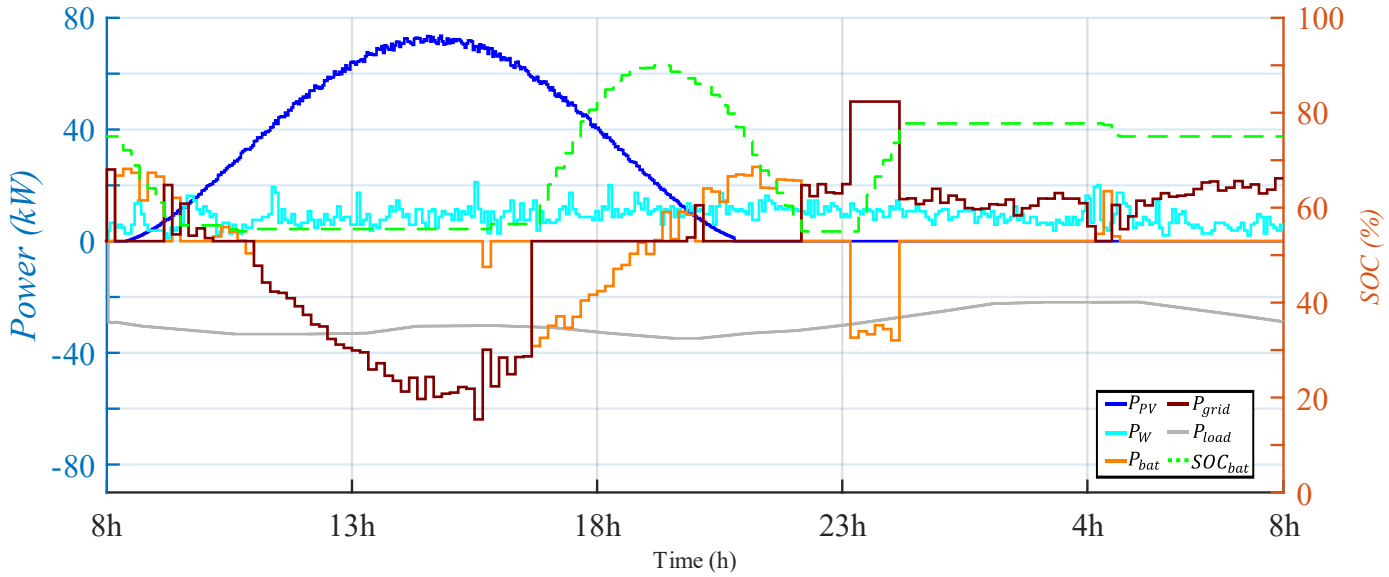

Fig. 4. 15. Power and SOC profiles obtained for scenario 5 and community application.

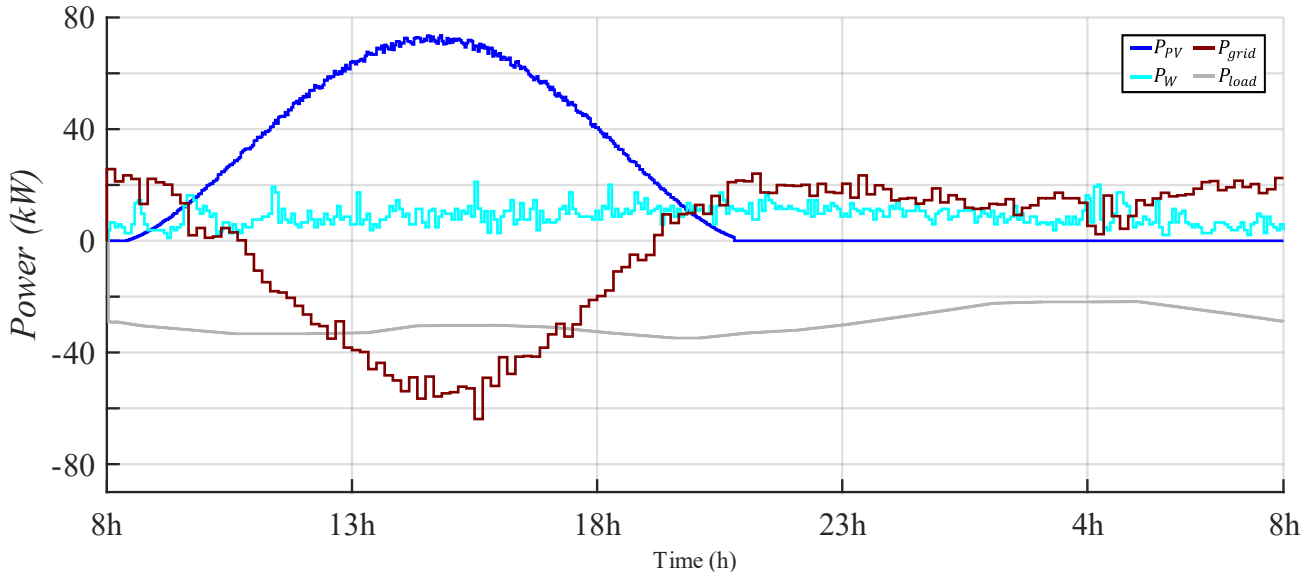

Fig. 4. 16. Power and SOC profiles obtained for scenario 5 and community application.

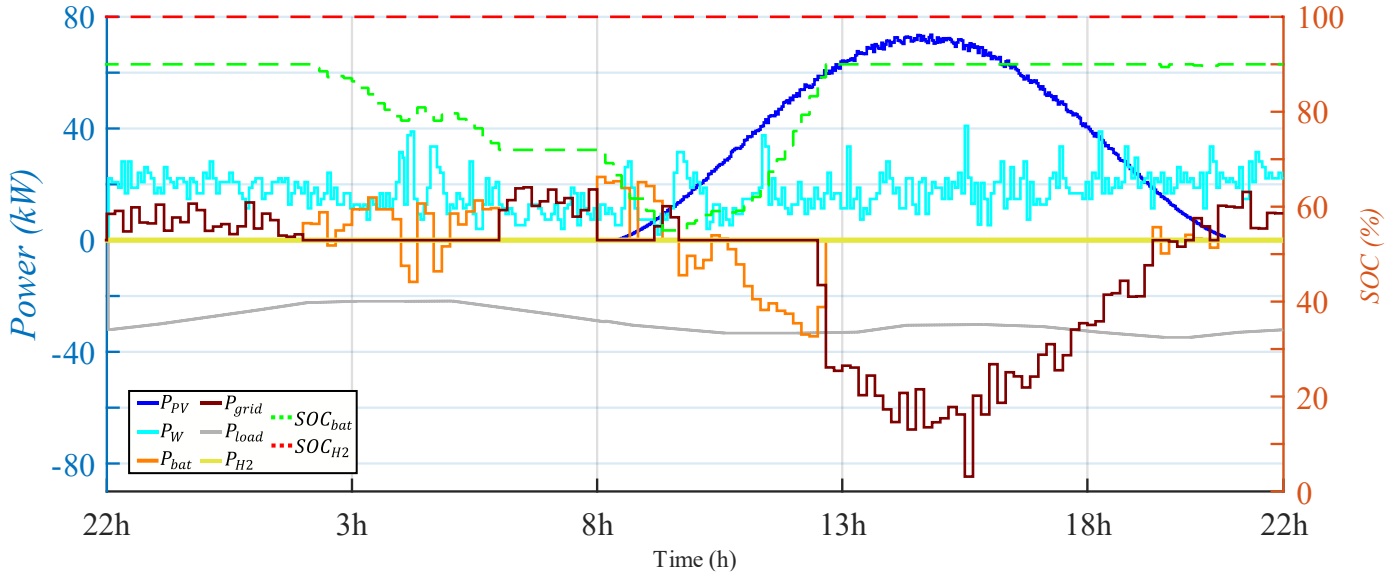

Fig. 4. 17. Power and SOC profiles obtained for scenario 6 and community application.

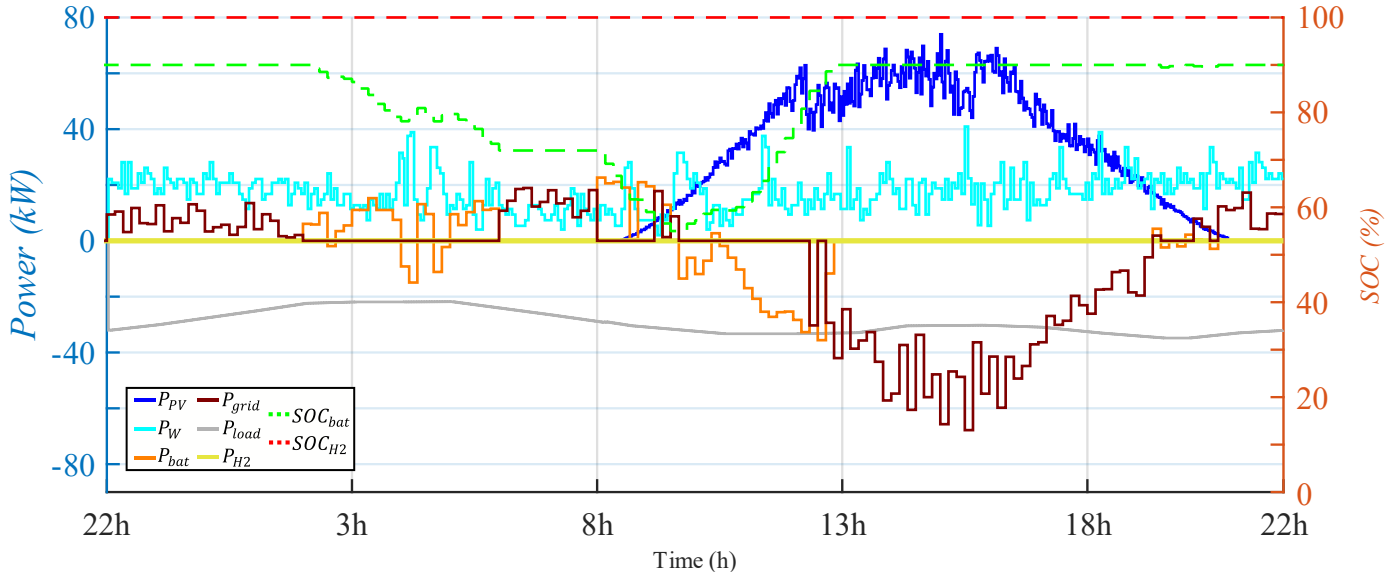

Fig. 4. 18. Power and SOC profiles obtained for scenario 7 and community application.

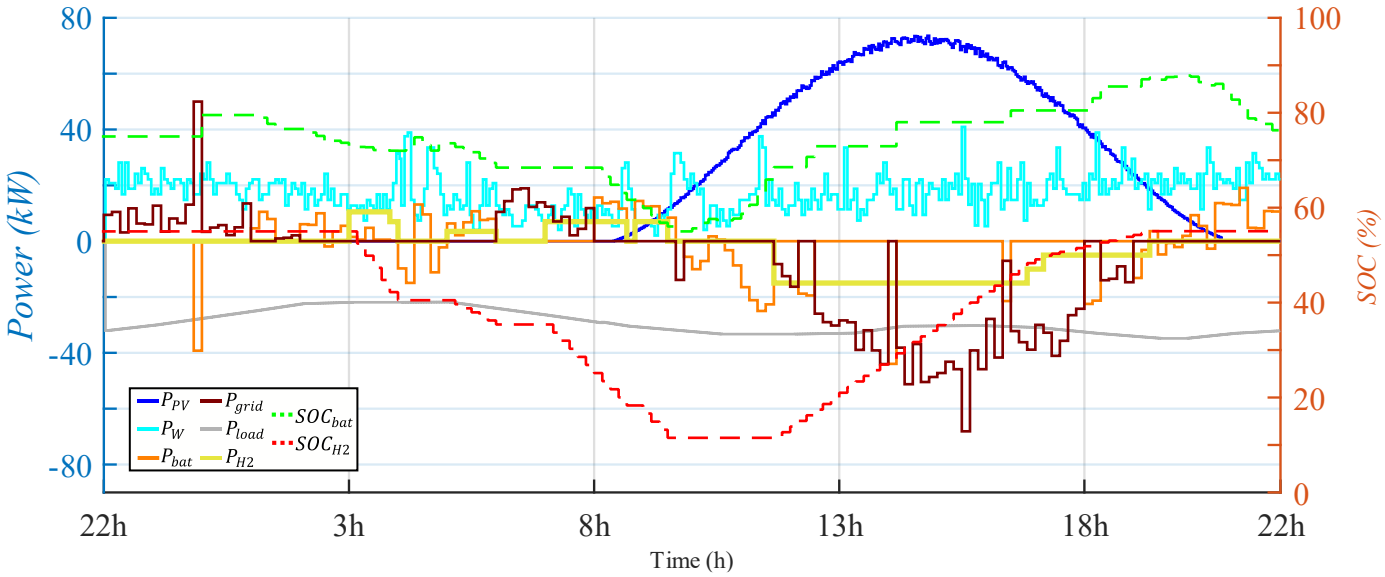

Fig. 4. 19. Power and SOC profiles obtained for scenario 8 and community application.

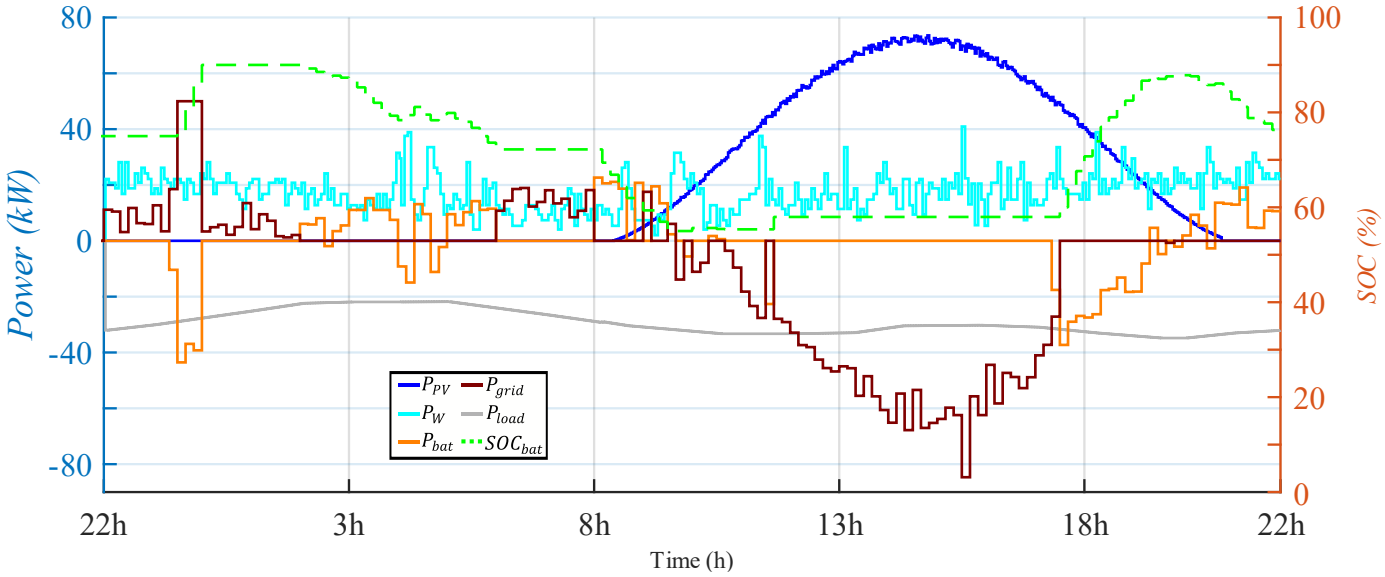

Fig. 4. 20. Power and SOC profiles obtained for scenario 8 and community application.

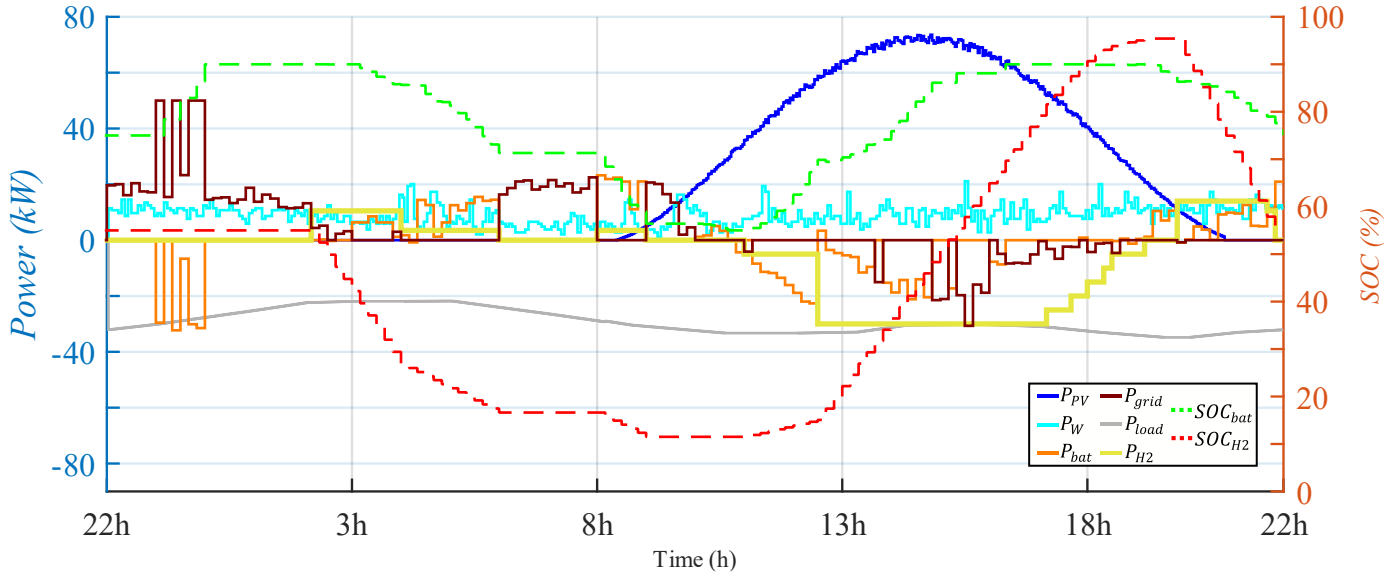

Fig. 4. 21. Power and SOC profiles obtained for scenario 9 and community application.

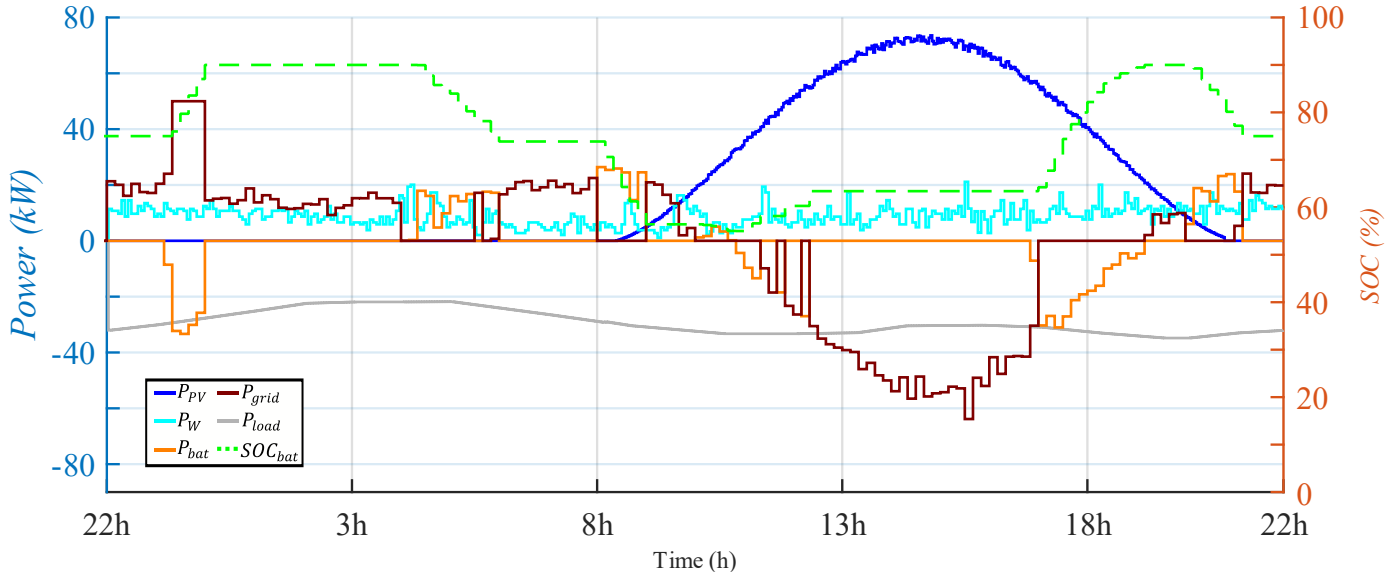

Fig. 4. 22. Power and SOC profiles obtained for scenario 9 and community application.

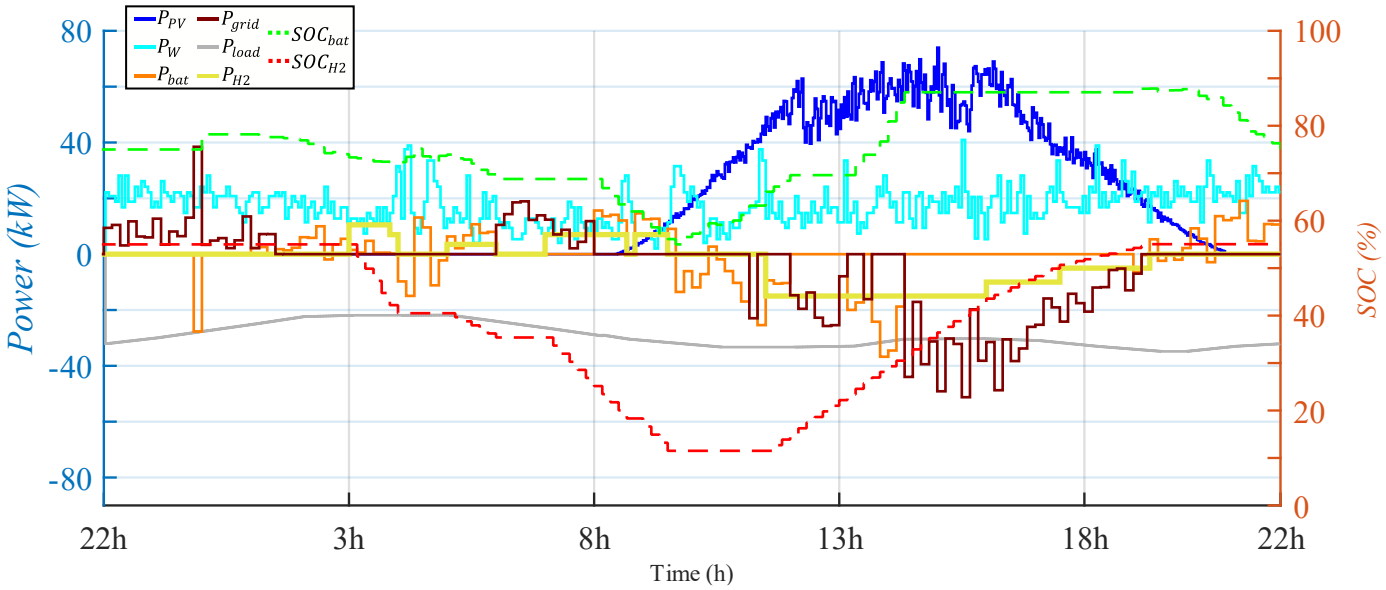

Fig. 4. 23. Power and SOC profiles obtained for scenario 10 and community application.

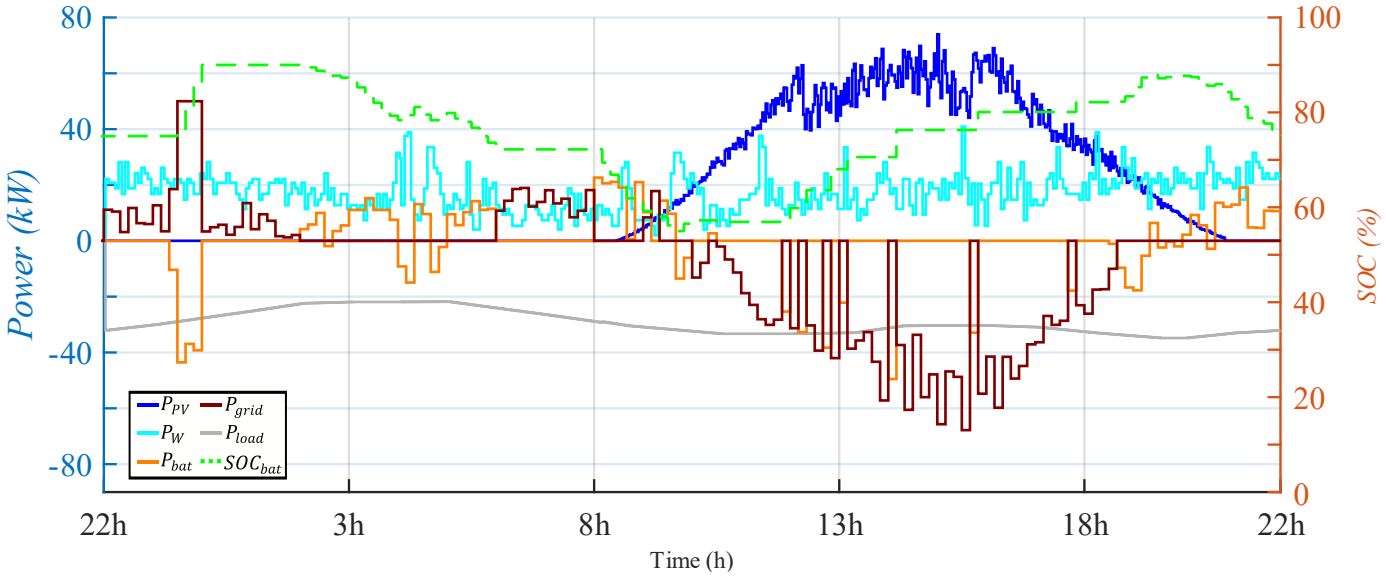

Fig. 4. 24. Power and SOC profiles obtained for scenario 10 and community application.

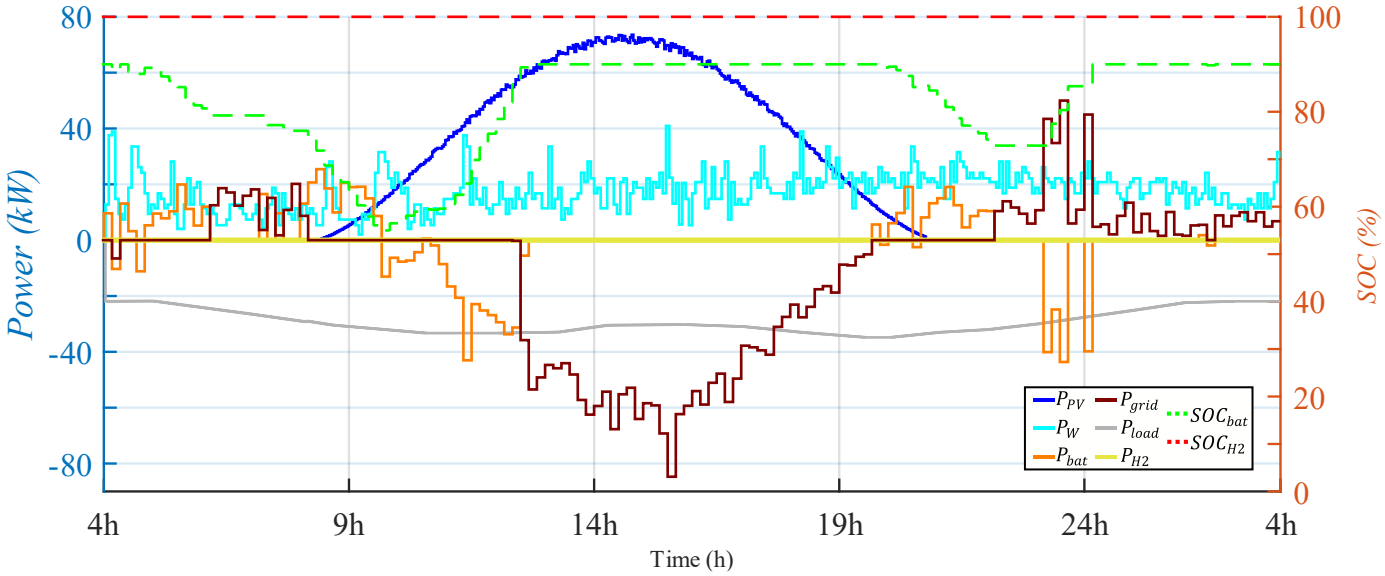

Fig. 4. 25. Power and SOC profiles obtained for scenario 11 and community application.

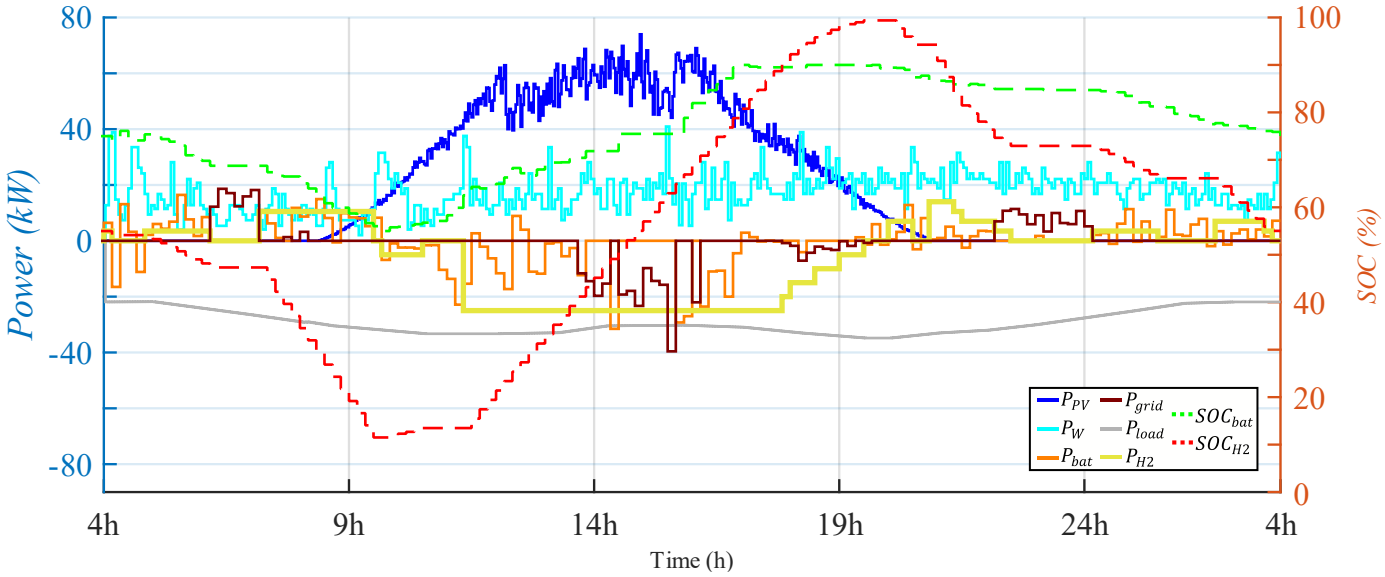

Fig. 4. 26. Power and SOC profiles obtained for scenario 12 and community application.

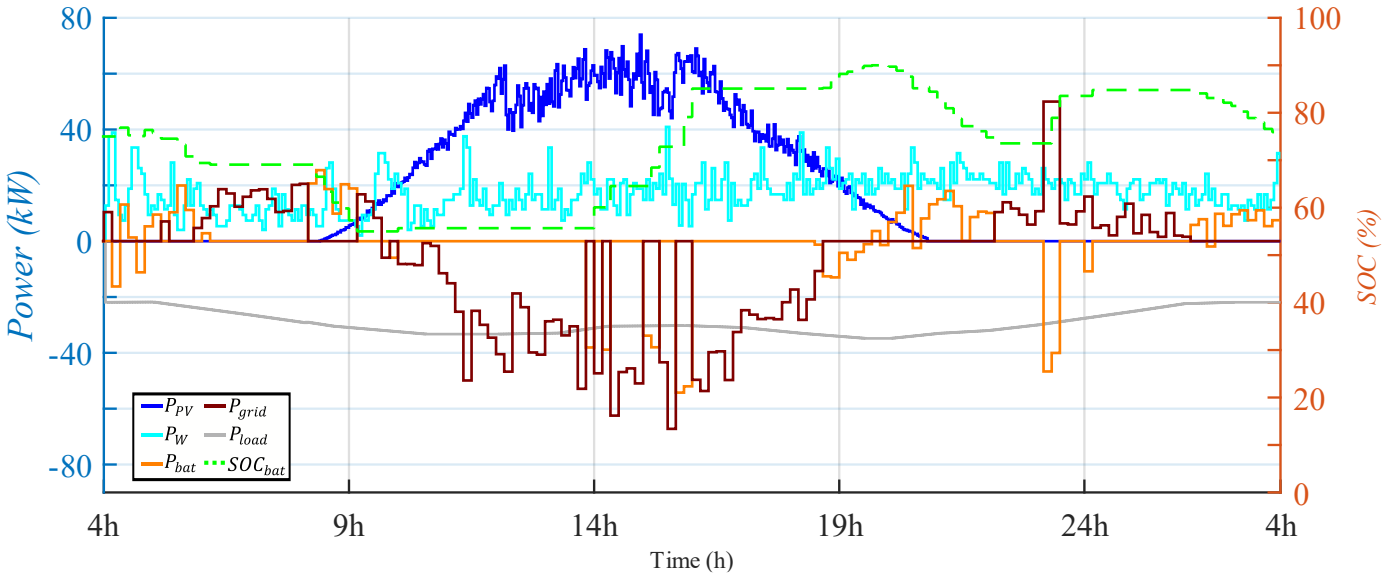

Fig. 4. 27. Power and SOC profiles obtained for scenario 12 and community application.

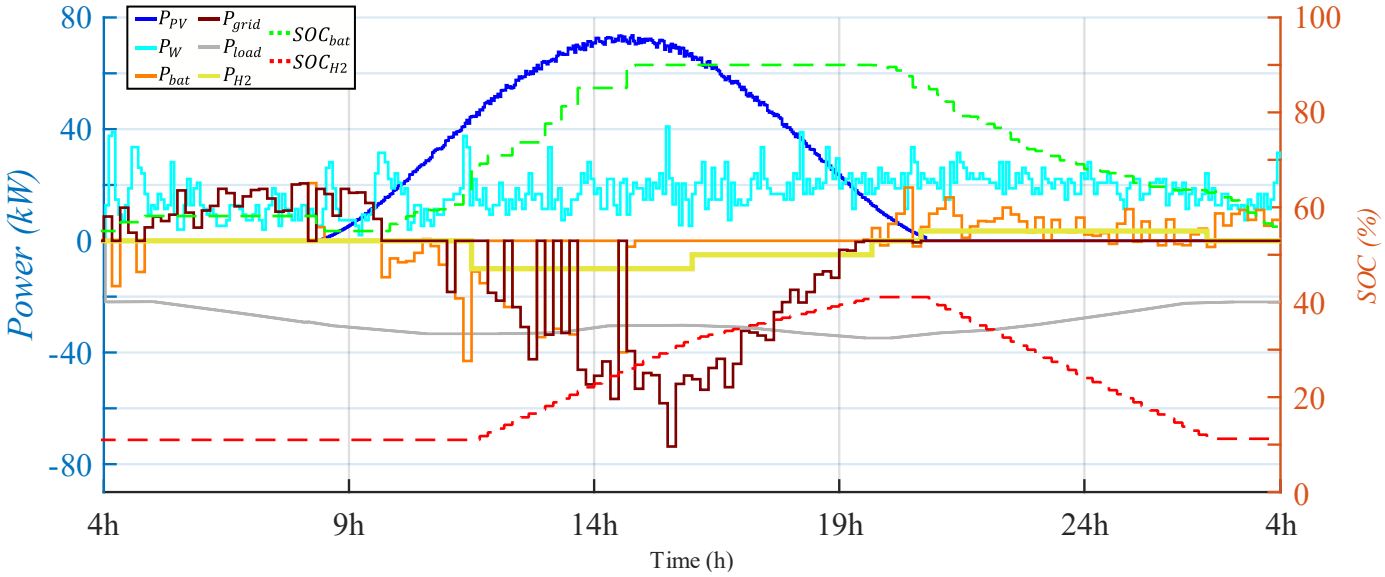

Fig. 4. 28. Power and SOC profiles obtained for scenario 13 and community application.

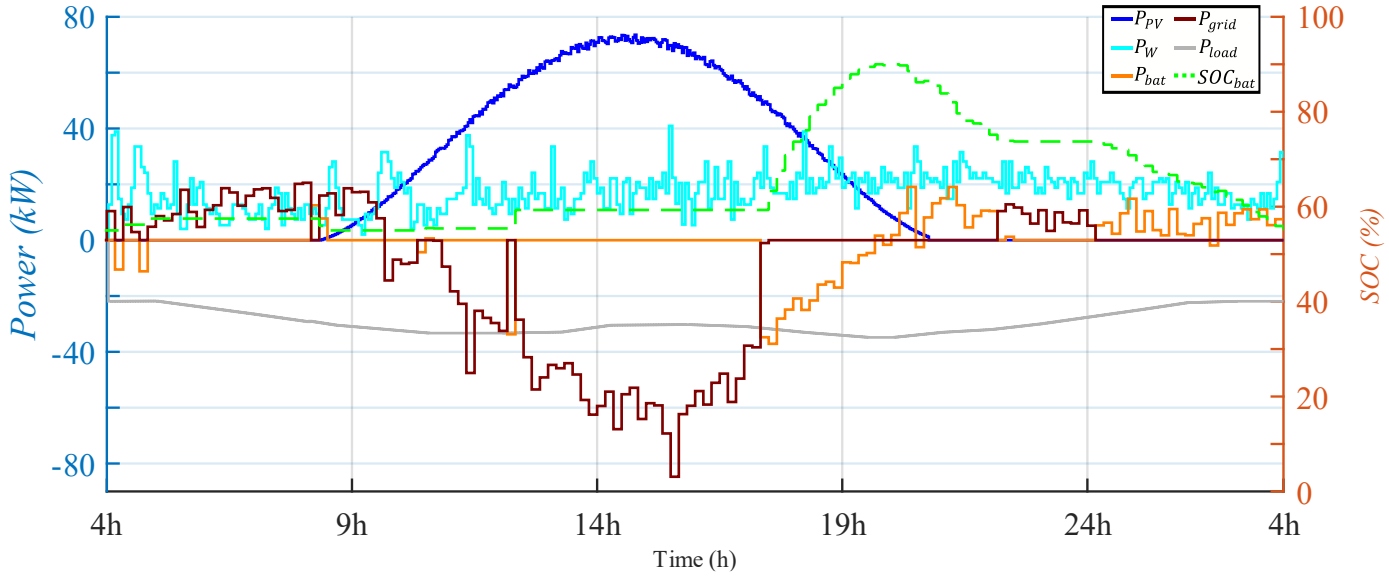

Fig. 4. 29. Power and SOC profiles obtained for scenario 13 and community application.

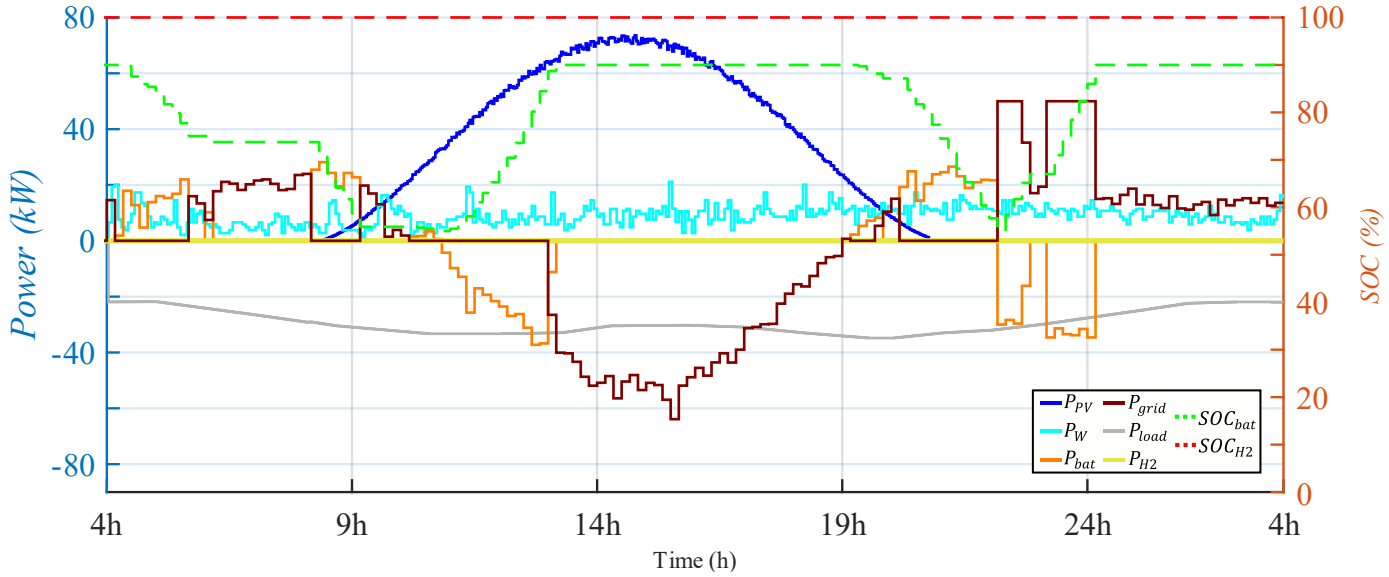

Fig. 4. 30. Power and SOC profiles obtained for scenario 14 and community application.

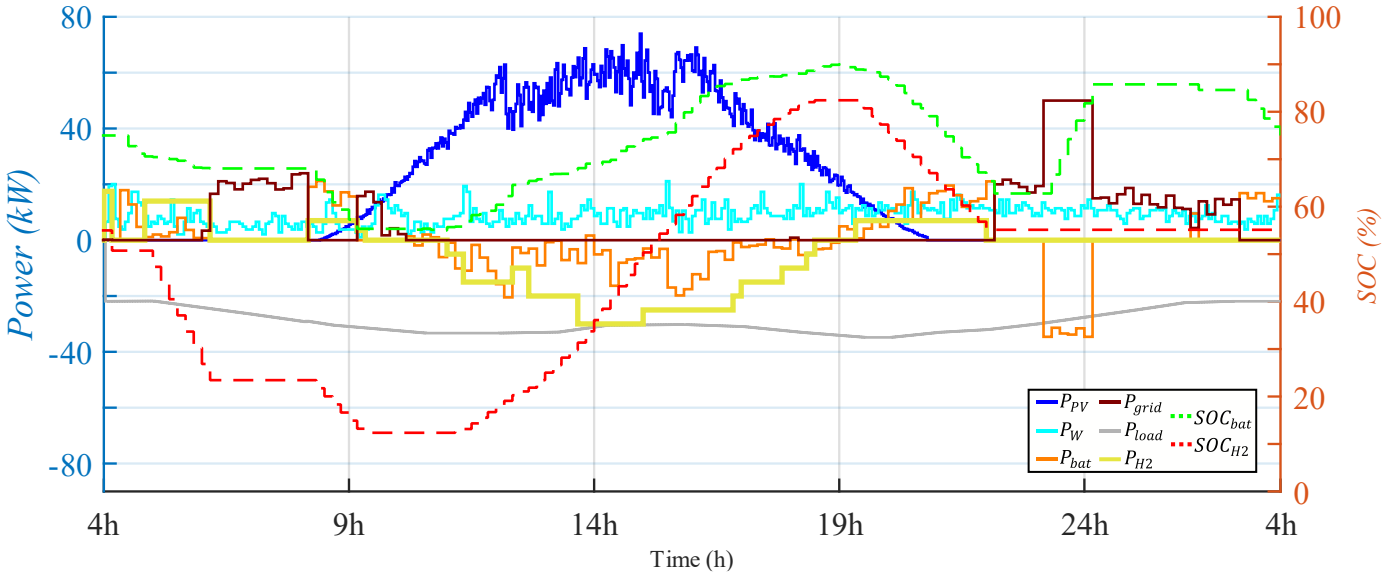

Fig. 4. 31. Power and SOC profiles obtained for scenario 15 and community application.

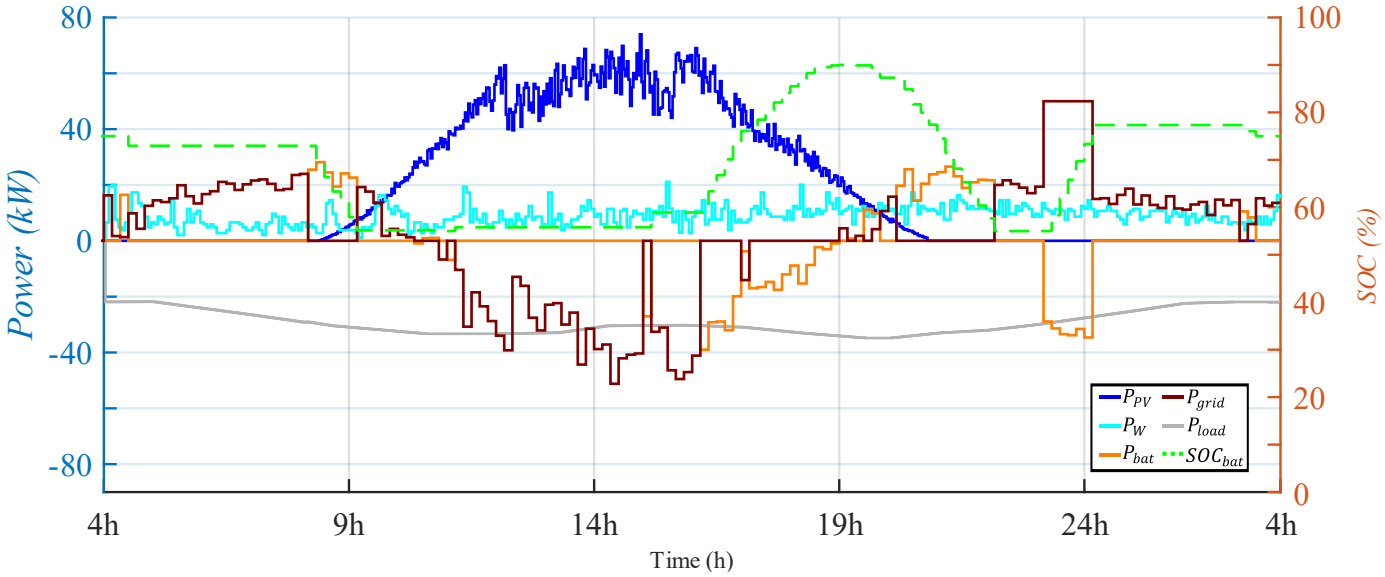

Fig. 4. 32. Power and SOC profiles obtained for scenario 15 and community application.

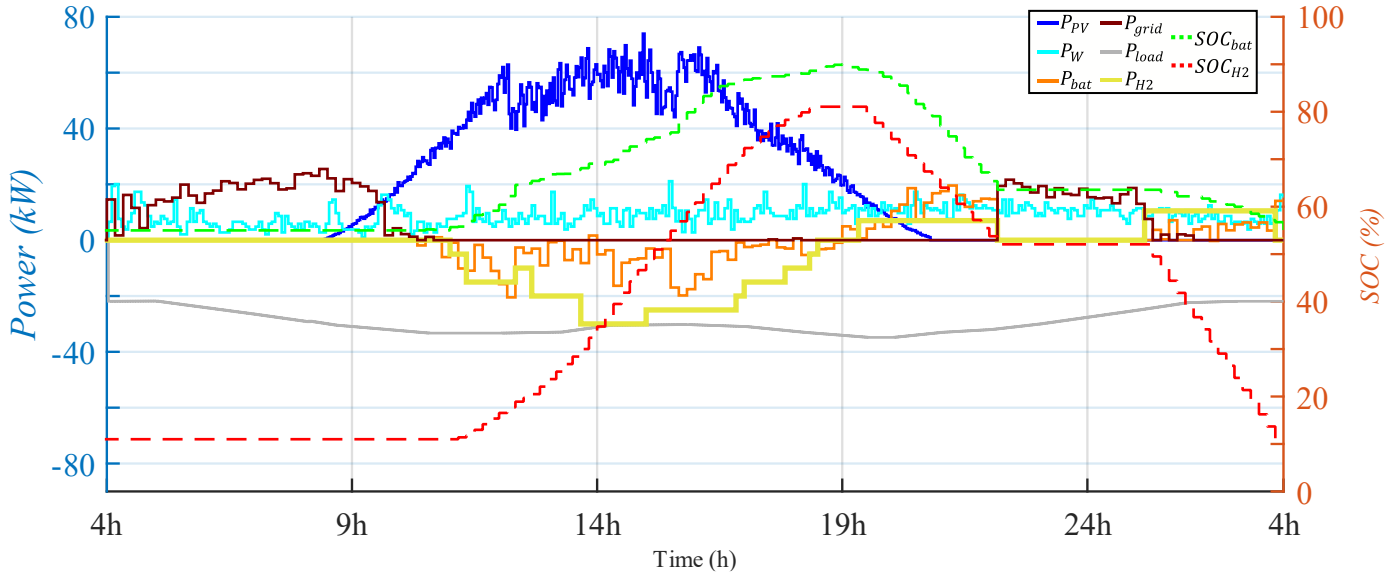

Fig. 4. 33. Power and SOC profiles obtained for scenario 16 and community application.

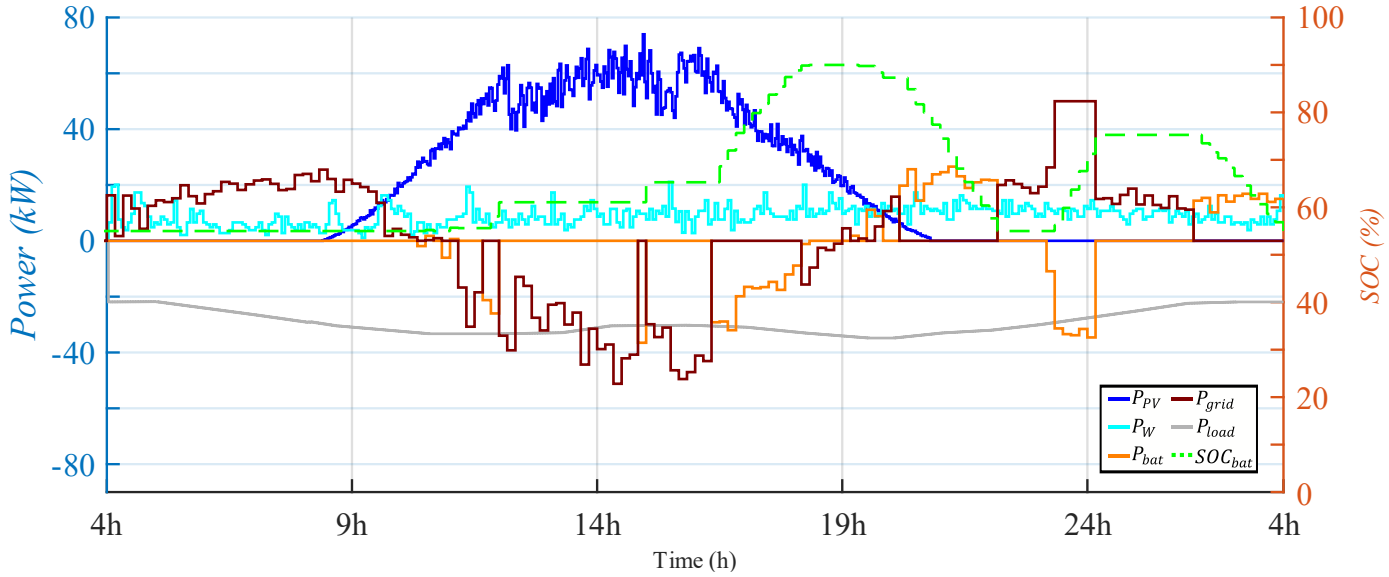

Fig. 4. 34. Power and SOC profiles obtained for scenario 16 and community application.

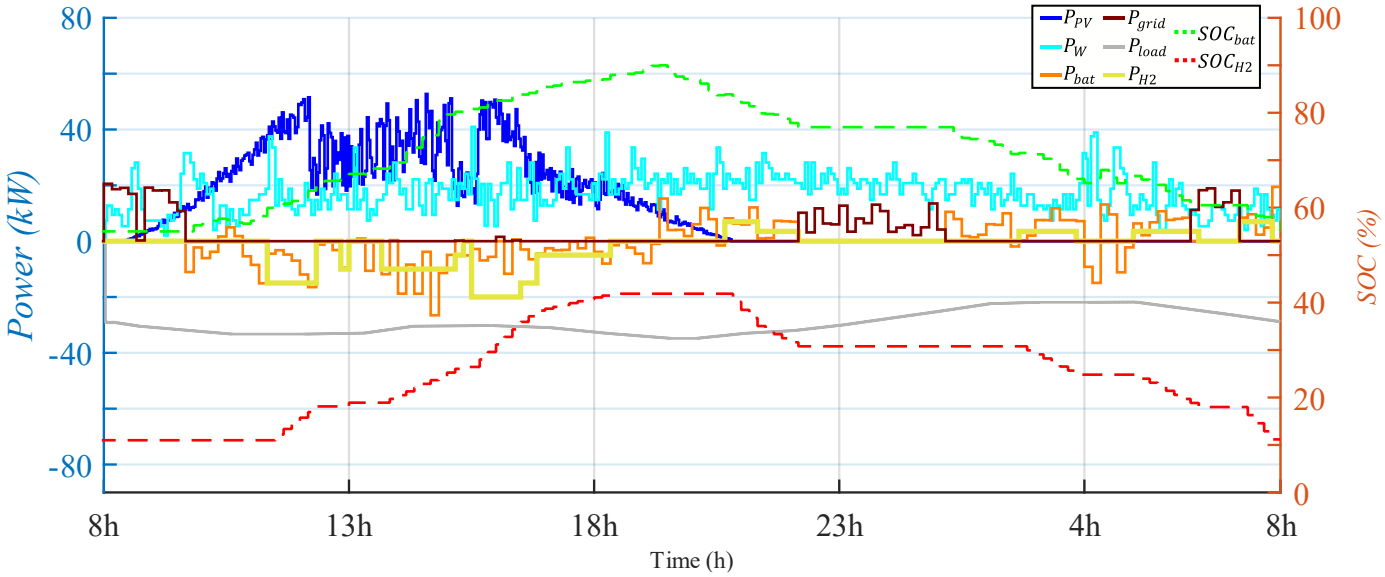

Fig. 4. 35. Power and SOC profiles obtained for scenario 17 and community application.

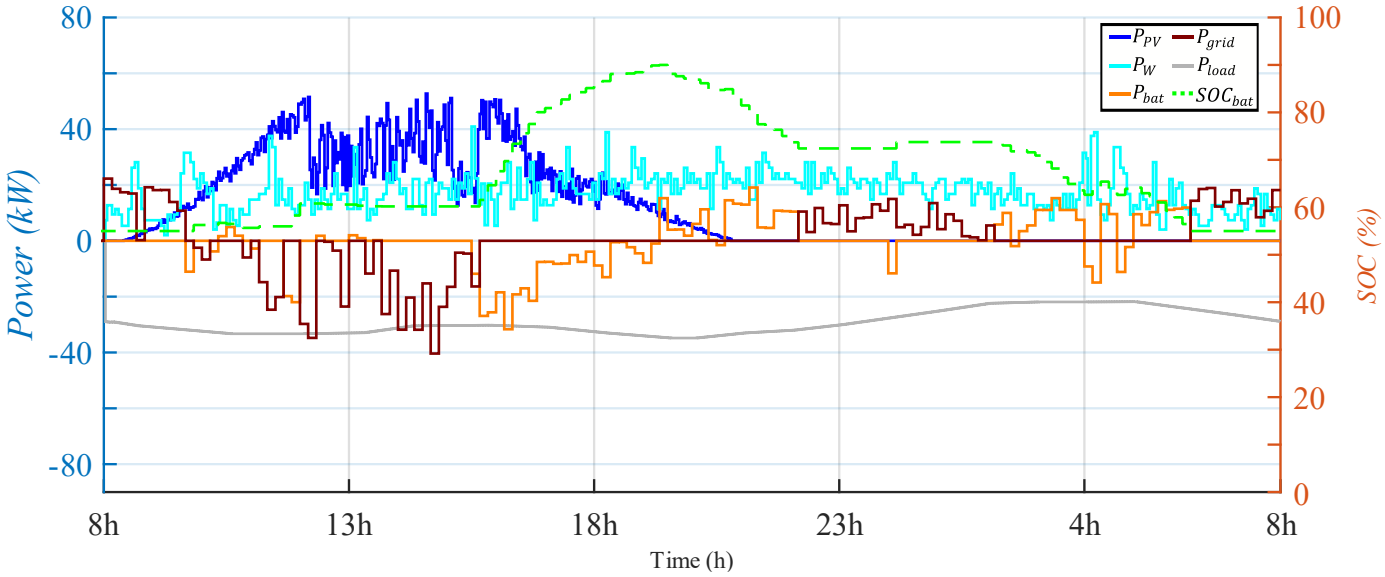

Fig. 4. 36. Power and SOC profiles obtained for scenario 17 and community application.

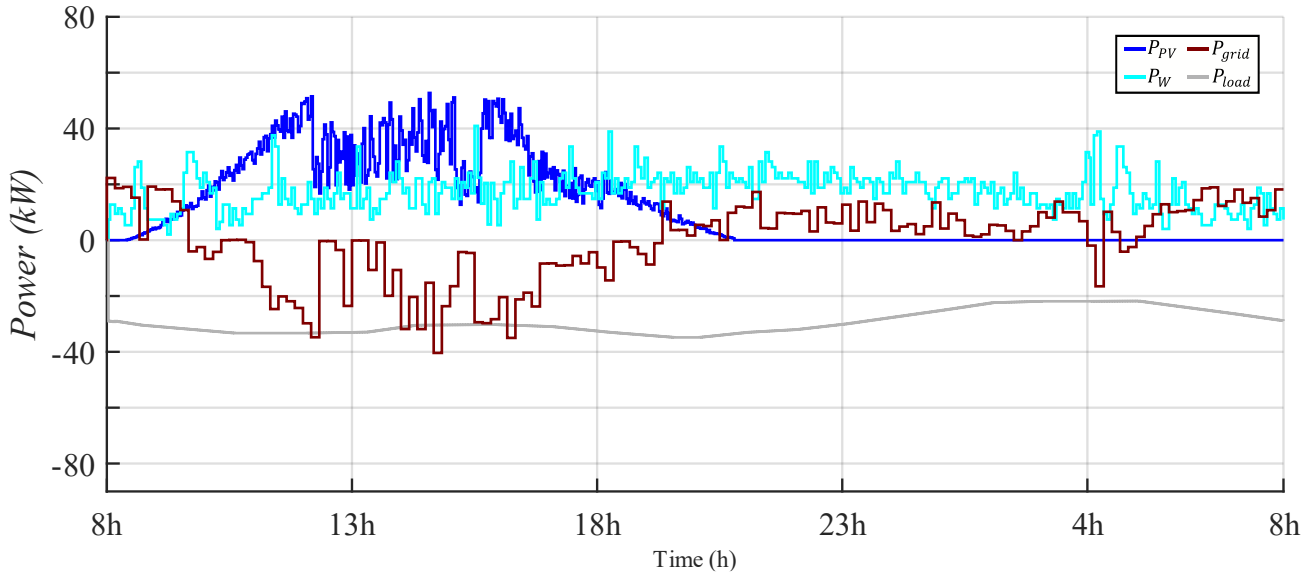

Fig. 4. 37. Power and SOC profiles obtained for scenario 17 and community application.

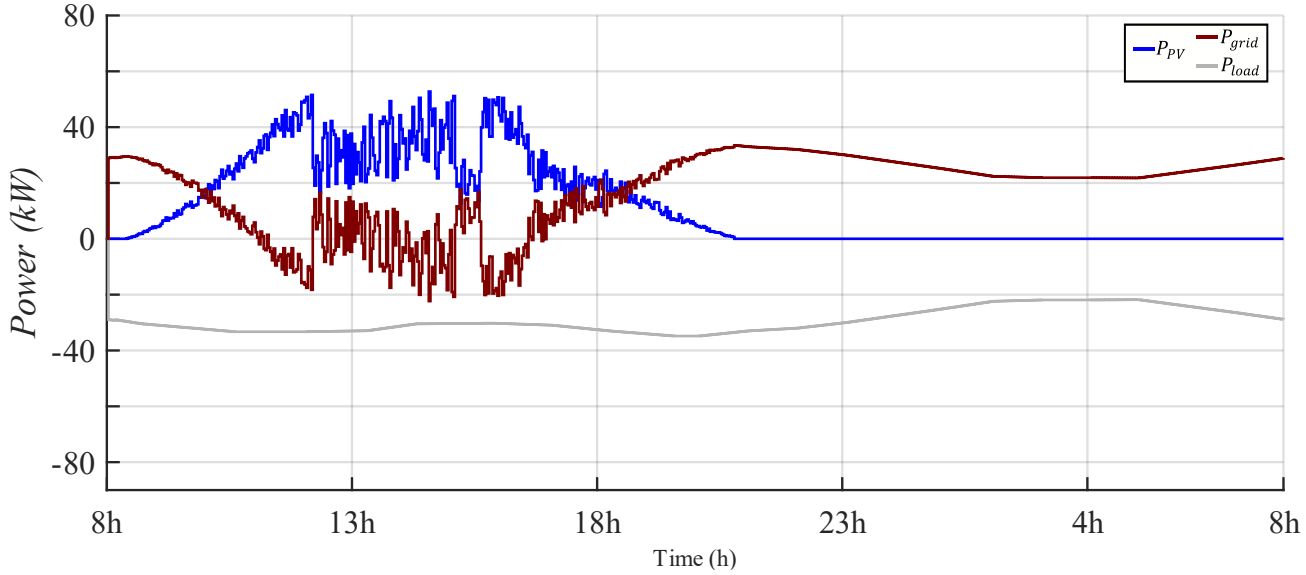

Fig. 4. 38. Power and SOC profiles obtained for scenario 17 and 18 and community application.

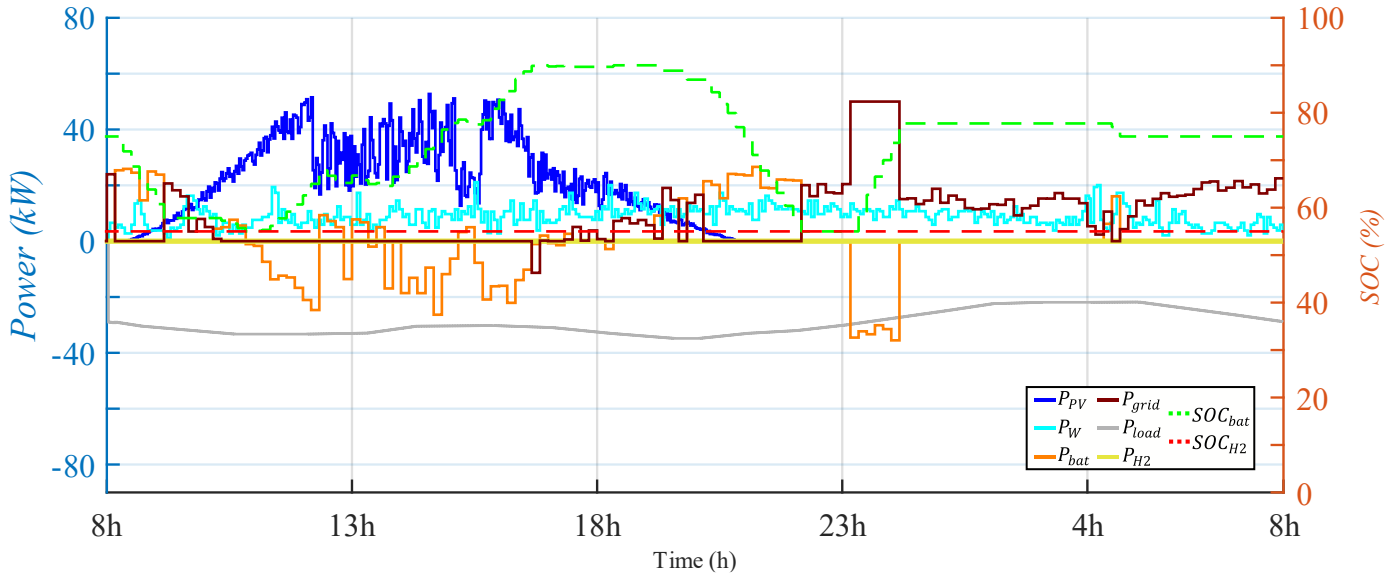

Fig. 4. 39. Power and SOC profiles obtained for scenario 18 and community application.

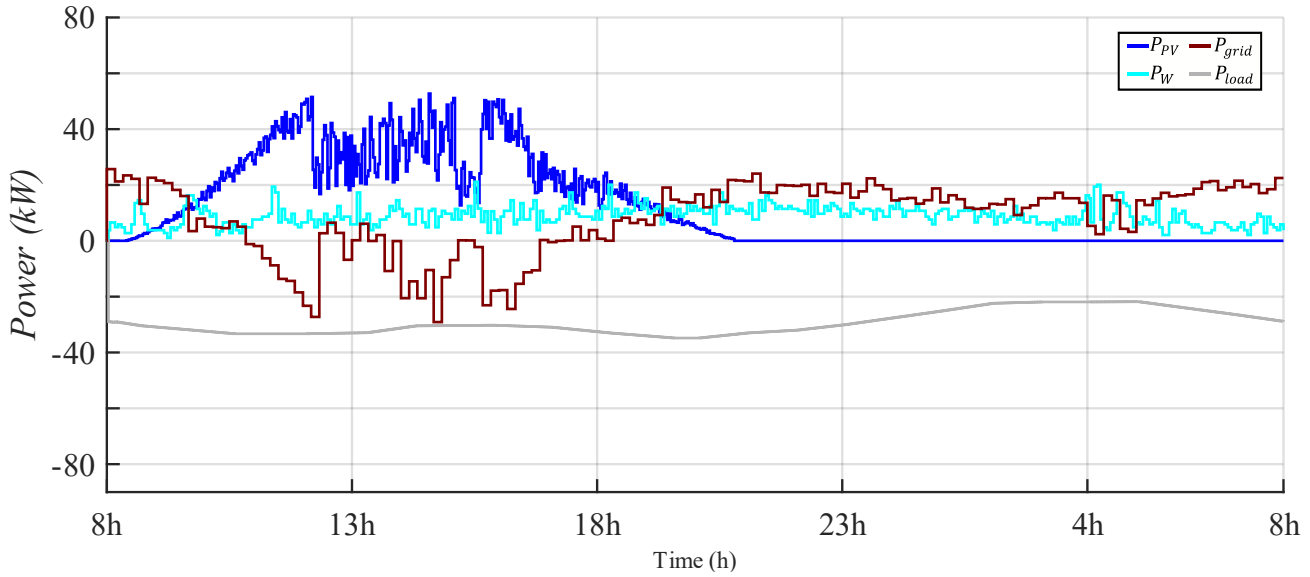

Fig. 4. 40. Power and SOC profiles obtained for scenario 18 and community application.

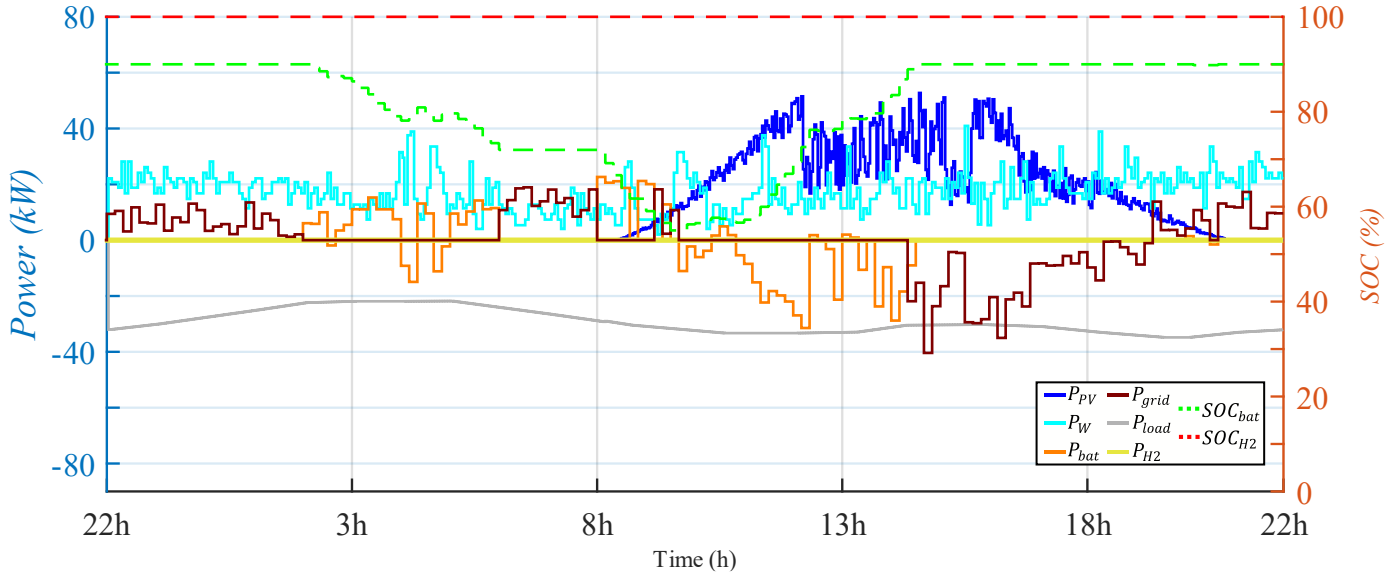

Fig. 4. 41. Power and SOC profiles obtained for scenario 19 and community application.

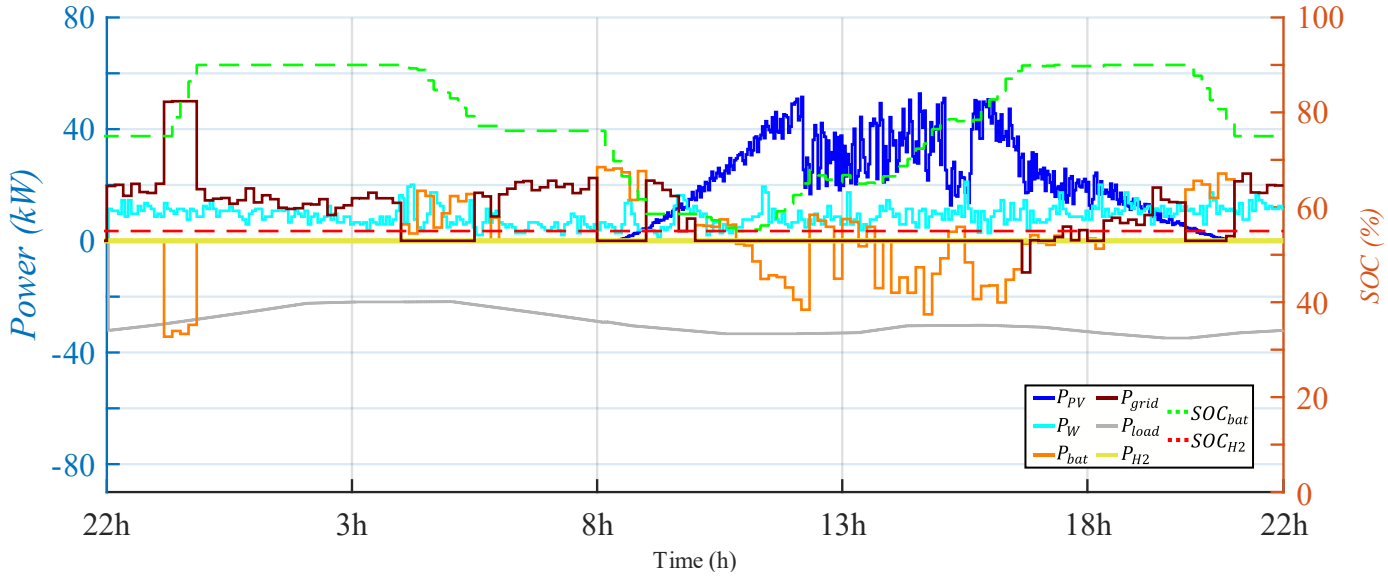

Fig. 4. 42. Power and SOC profiles obtained for scenario 20 and community application.

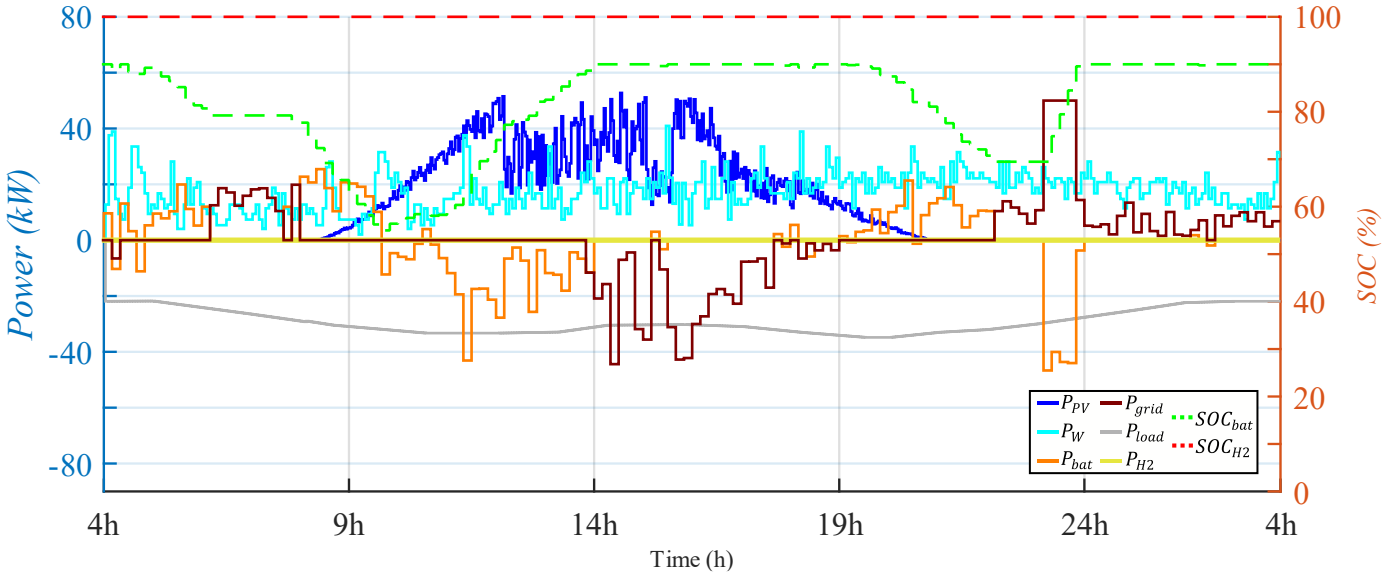

Fig. 4. 43. Power and SOC profiles obtained for scenario 21 and community application.

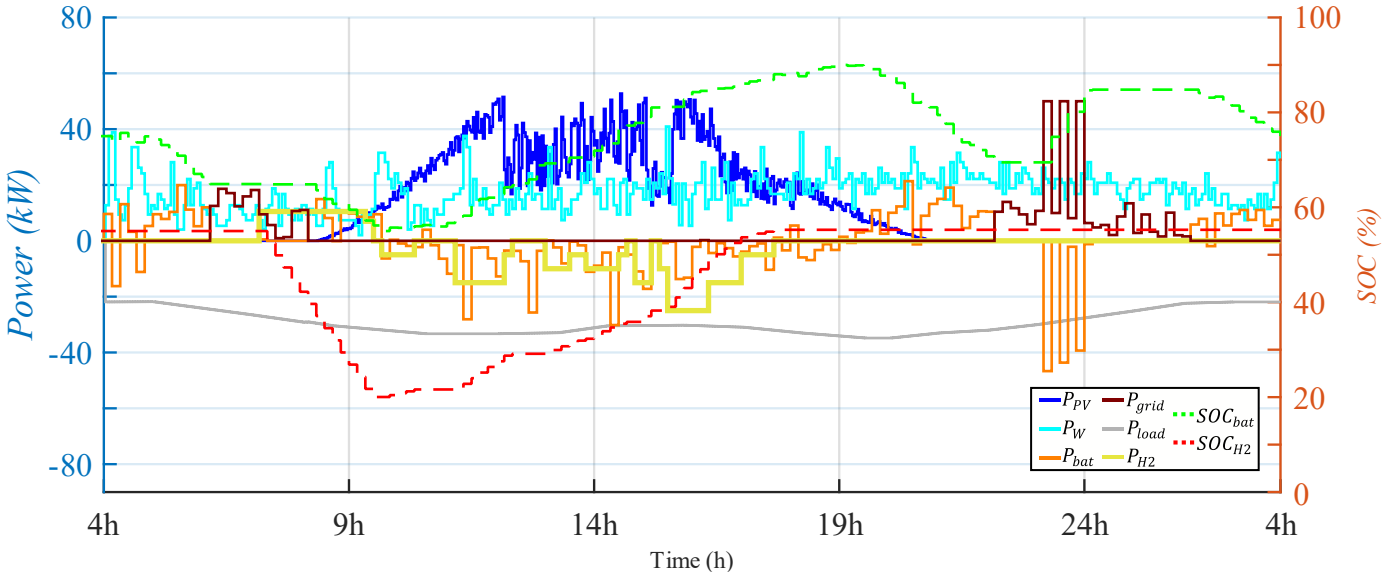

Fig. 4. 44. Power and SOC profiles obtained for scenario 22 and community application.

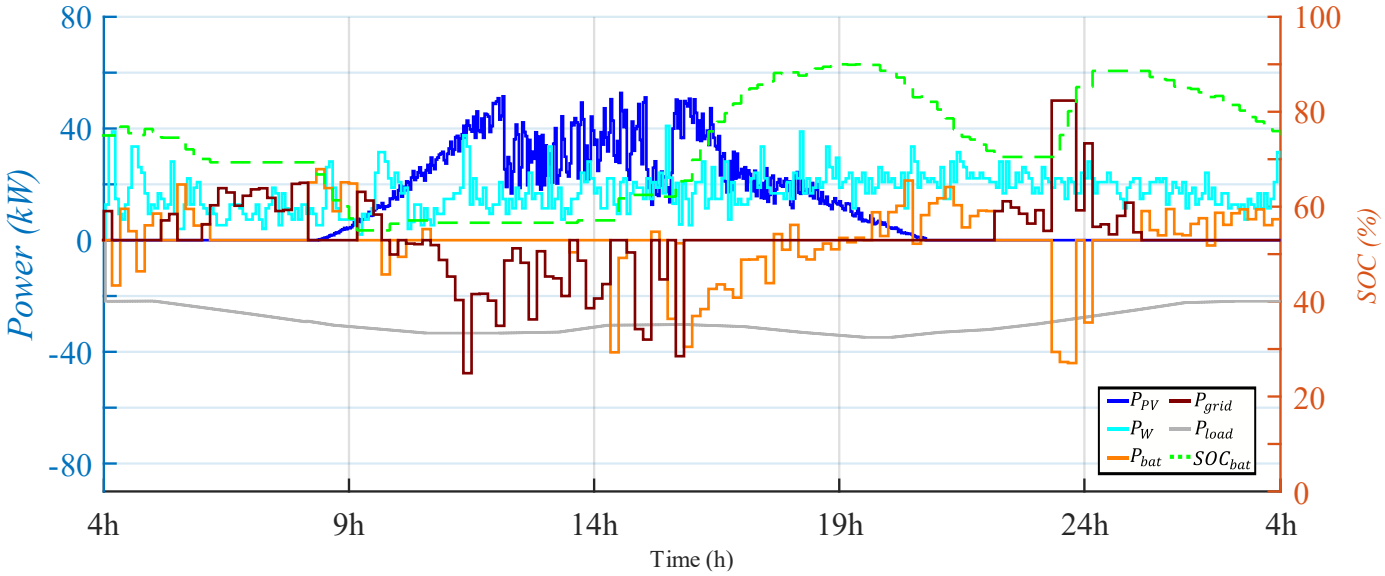

Fig. 4. 45. Power and SOC profiles obtained for scenario 22 and community application.

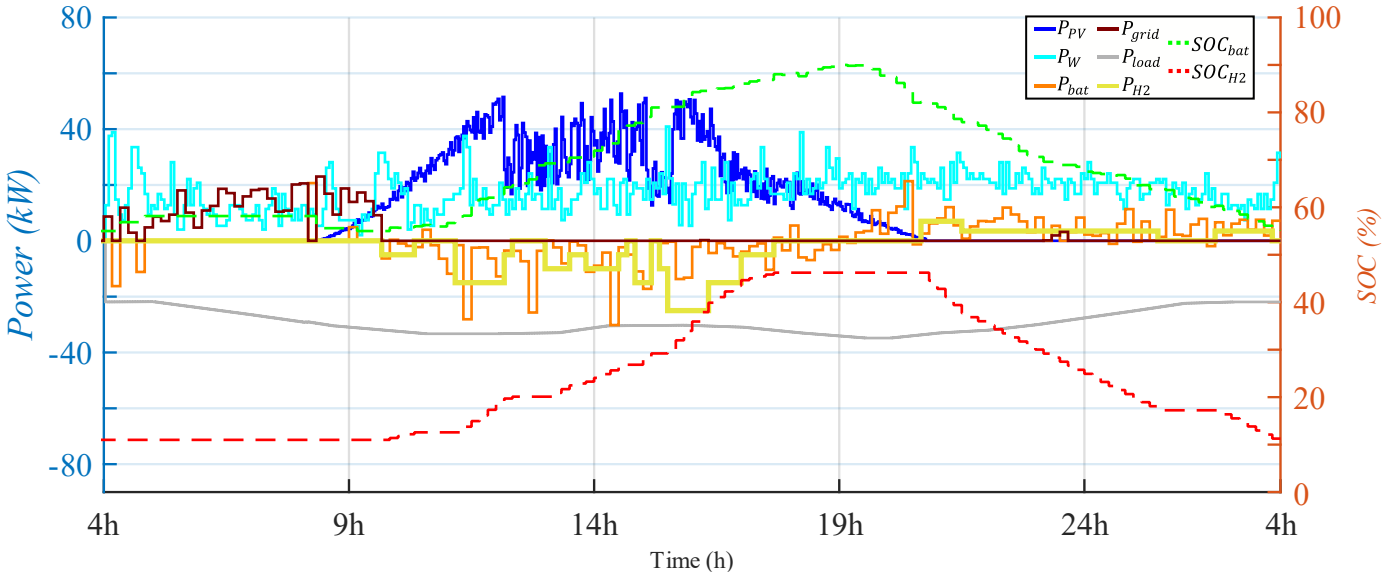

Fig. 4. 46. Power and SOC profiles obtained for scenario 23 and community application.

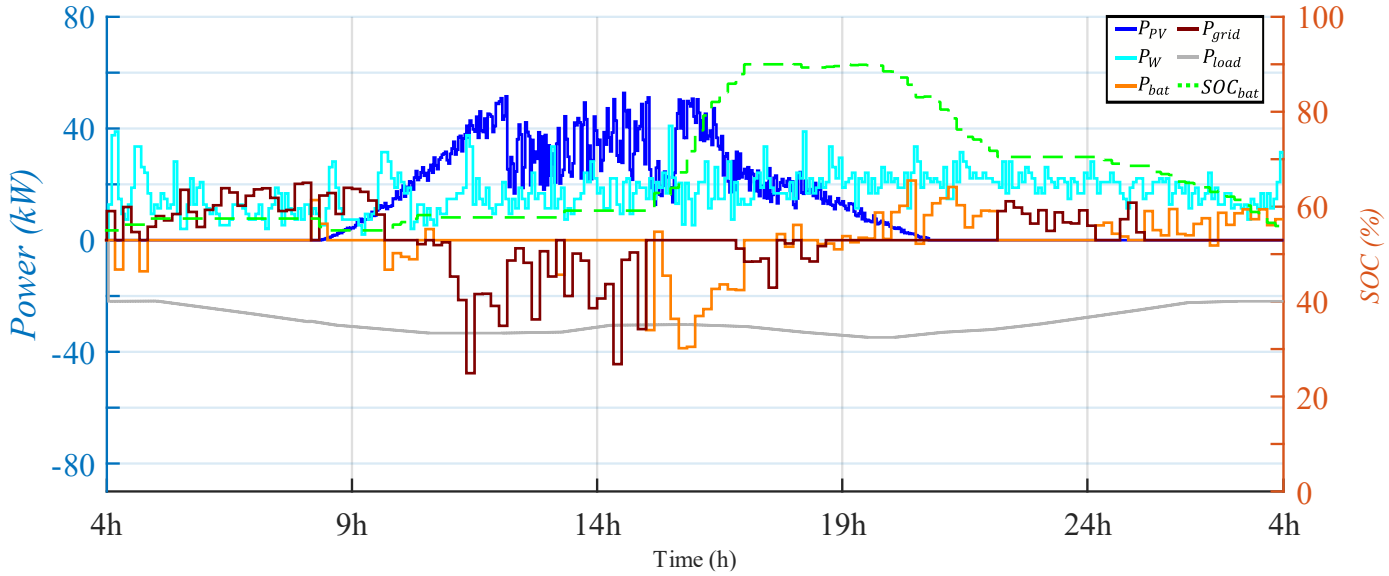

Fig. 4. 47. Power and SOC profiles obtained for scenario 23 and community application.

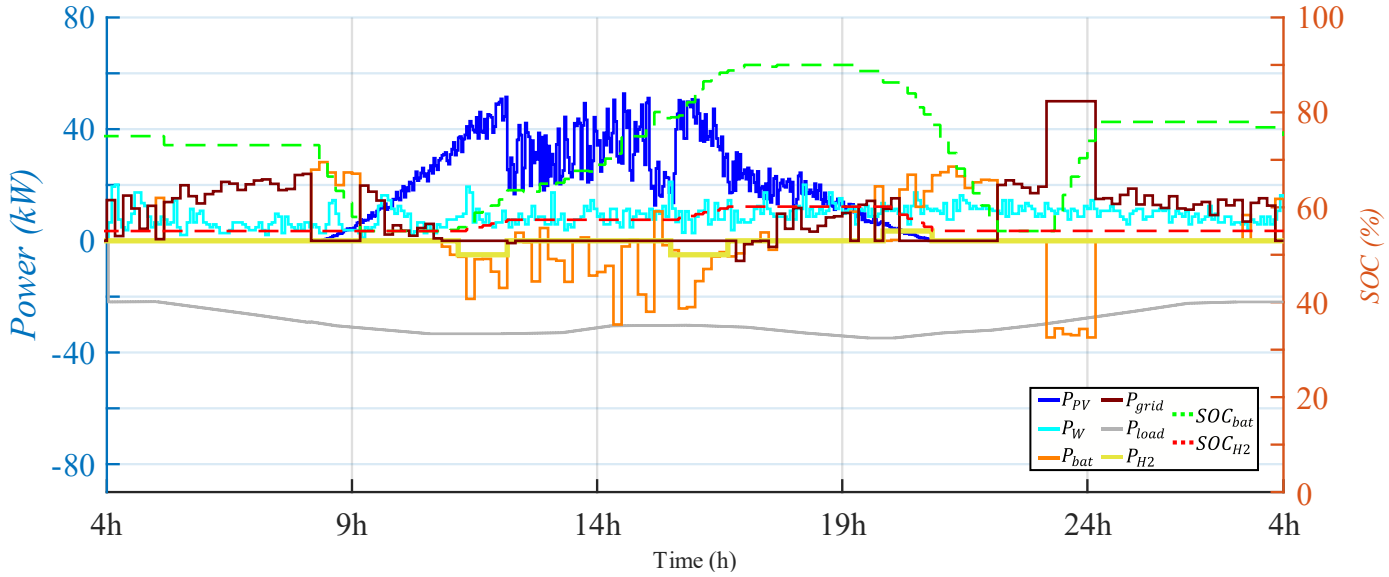

Fig. 4. 48. Power and SOC profiles obtained for scenario 24 and community application.

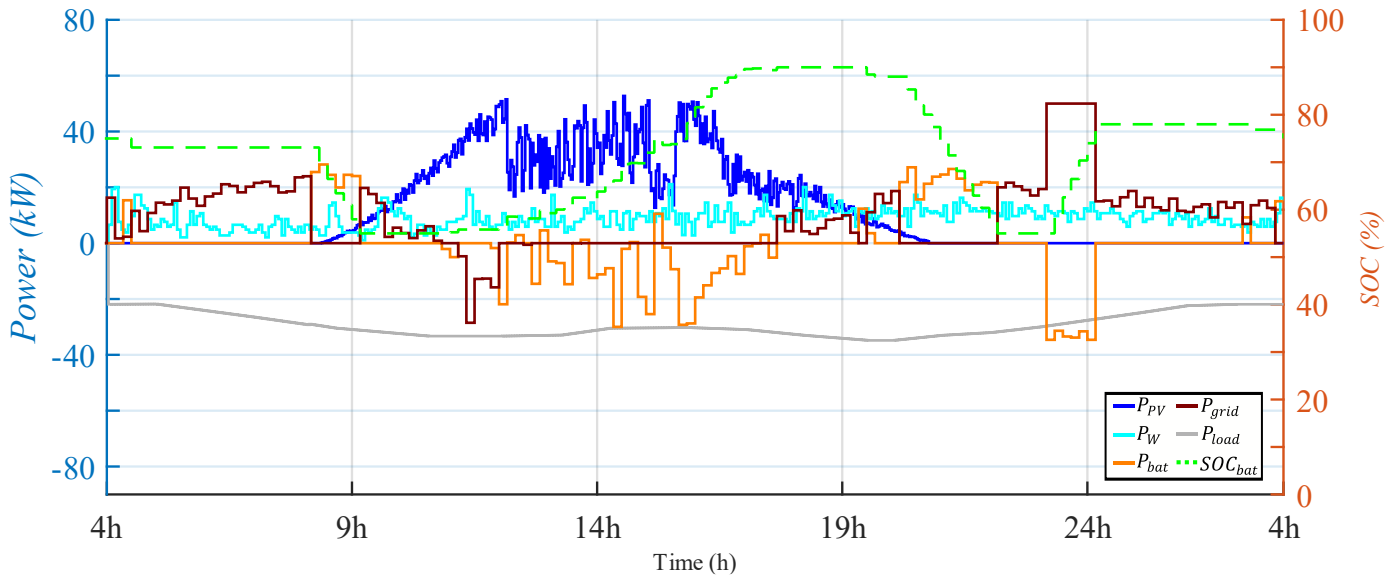

Fig. 4. 49. Power and SOC profiles obtained for scenario 24 and community application.

Table 4. Results obtained in the microgrid architecture for community application (case 4, Fig. 1). $PH = 24\ h.\ T_s = 0.1\hat{6}\ h.(600\ sec.)$.

Scenario			Cost									Computational cost[2] (sec.)
Number	Day	Initial conditions	$\mathbf{Cost_{MPC}}$ (€)	$\mathbf{Cost_{MPC}/Cost_{MEG}}$ (%)	$\mathbf{Cost^{BSS}_{MPC}}$ (€)	$\mathbf{Cost^{BSS}_{MPC}/Cost_{MEG}}$ (%)	$\mathbf{Cost_{ren}}$ (€)	$\mathbf{Cost_{ren}/Cost_{MEG}}$ (%)	$\mathbf{Cost^{PV}_{ren}}$ (€)	$\boldsymbol{Cost^{PV}_{ren}/Cost_{MEG}}$ (%)	$\boldsymbol{Cost_{MEG}}$ (€)	
1	Sunny and high wind	Starts at 8h $SOC^{ini}_{bat} = 55\%$ $SOC^{ini}_{H2} = 11\%$	4.30 Fig. 4. 1	1.71	12.28 Fig. 4. 2	4.88	32.53 Fig. 4. 3	12.91	135.99 Fig. 4. 4	53.99	251.89 Fig. 4. 5	11.64 ($Cost_{MPC}$) 0.91 ($Cost^{BSS}_{MPC}$)
2	Sunny with clouds and high wind	Starts at 8h $SOC^{ini}_{bat} = 55\%$ $SOC^{ini}_{H2} = 11\%$	7.77 Fig. 4. 6	3.08	15.90 Fig. 4. 7	6.31	36.07 Fig. 4. 8	14.32	140.71 Fig. 4. 9	55.86	251.89 Fig. 4. 5	12.64 ($Cost_{MPC}$) 0.98 ($Cost^{BSS}_{MPC}$)
3	Sunny with clouds and high wind	Starts at 8h $SOC^{ini}_{bat} = 75\%$ $SOC^{ini}_{H2} = 55\%$	10.28 Fig. 4. 10	4.08	15.17 Fig. 4. 11	6.02	36.07 Fig. 4.8	14.32	140.71 Fig. 4. 9	55.86	251.89 Fig. 4. 5	6.67 ($Cost_{MPC}$) 0.83 ($Cost^{BSS}_{MPC}$)
4	Sunny and high wind	Starts at 8h $SOC^{ini}_{bat} = 75\%$ $SOC^{ini}_{H2} = 55\%$	6.71 Fig. 4. 12	2.66	11.56 Fig. 4. 13	4.59	32.53 Fig. 4. 3	12.91	135.99 Fig. 4. 4	53.99	251.89 Fig. 4. 5	5.48 ($Cost_{MPC}$) 0.80 ($Cost^{BSS}_{MPC}$)
5	Sunny and low wind	Starts at 8h $SOC^{ini}_{bat} = 75\%$ $SOC^{ini}_{H2} = 55\%$	51.63 Fig. 4. 14	20.50	59.04 Fig. 4. 15	23.44	79.79 Fig. 4. 16	31.68	135.99 Fig. 4. 4	53.99	251.89 Fig. 4. 5	7.26 ($Cost_{MPC}$) 0.89 ($Cost^{BSS}_{MPC}$)
6	Sunny and high wind	Starts at 22h $SOC^{ini}_{bat} = 90\%$ $SOC^{ini}_{H2} = 100\%$	13.48 Fig. 4. 17	5.35	13.48 Fig. 4. 17	5.35	32.53	12.91	135.99	53.99	251.89	795.60($Cost_{MPC}$) 0.77 ($Cost^{BSS}_{MPC}$)
7	Sunny with clouds and high wind	Starts at 22h $SOC^{ini}_{bat} = 90\%$ $SOC^{ini}_{H2} = 100\%$	16.76 Fig. 4. 18	6.65	16.76 Fig. 4. 18	6.65	36.07	14.32	140.71	*55.86*	251.89	2792 ($Cost_{MPC}$) 0.75 ($Cost^{BSS}_{MPC}$)
8	Sunny and high wind	Starts at 22h $SOC^{ini}_{bat} = 75\%$ $SOC^{ini}_{H2} = 55\%$	7.58 Fig. 4. 19	3.01	12.51 Fig. 4. 20	4.97	32.53	12.91	135.99	*53.99*	251.89	2.05($Cost_{MPC}$) 0.69 ($Cost^{BSS}_{MPC}$)
9	Sunny and low wind	Starts at 22h $SOC^{ini}_{bat} = 75\%$ $SOC^{ini}_{H2} = 55\%$	49.14 Fig. 4. 21	19.51	60.74 Fig. 4. 22	24.11	79.79	31.68	135.99	*53.99*	251.89	21.24 ($Cost_{MPC}$) 0.72 ($Cost^{BSS}_{MPC}$)
10	Sunny with clouds and high wind	Starts at 22h $SOC^{ini}_{bat} = 75\%$ $SOC^{ini}_{H2} = 55\%$	10.82 Fig. 4. 23	4.30	15.75 Fig. 4. 24	6.25	36.07	14.32	140.71	*55.86*	251.89	2.56 ($Cost_{MPC}$) 0.78 ($Cost^{BSS}_{MPC}$)
11	Sunny and high wind	Starts at 4h $SOC^{ini}_{bat} = 90\%$ $SOC^{ini}_{H2} = 100\%$	15.98 Fig. 4. 25	6.34	15.98 Fig. 4. 25	6.34	32.53	12.91	135.99	*53.99*	251.89	719.53($Cost_{MPC}$) 0.69 ($Cost^{BSS}_{MPC}$)

[2] CPU processor Intel Core i7, 3.2 GHz with 16 GB RAM.

12	Sunny with clouds and high wind	Starts at 4h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 55\%$	9.39 Fig. 4. 26	3.73	18.93 Fig. 4. 27	7.52	36.07	14.32	140.71	*55.86*	251.89	11.63 ($Cost_{MPC}$) 0.81 ($Cost_{MPC}^{BSS}$)
13	Sunny and high wind	Starts at 4h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 11\%$	14.07 Fig. 4. 28	5.59	16.33 Fig. 4. 29	6.48	32.53	12.91	135.99	*53.99*	251.89	4.21 ($Cost_{MPC}$) 0.80 ($Cost_{MPC}^{BSS}$)
14	Sunny and low wind	Starts at 4h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$	61.29 Fig. 4. 30	24.33	61.29 Fig. 4. 30	24.33	79.79	31.68	135.99	*53.99*	251.89	1161 ($Cost_{MPC}$) 0.65 ($Cost_{MPC}^{BSS}$)
15	Sunny with clouds and low wind	Starts at 4h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 55\%$	56.56 Fig. 4. 31	22.45	64.82 Fig. 4. 32	25.73	83.78	33.26	140.71	*55.86*	251.89	17.68 ($Cost_{MPC}$) 1.03 ($Cost_{MPC}^{BSS}$)
16	Sunny with clouds and low wind	Starts at 4h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 11\%$	57.90 Fig. 4. 33	22.99	65.73 Fig. 4. 34	26.09	83.78	33.26	140.71	*55.86*	251.89	12.28 ($Cost_{MPC}$) 1.06 ($Cost_{MPC}^{BSS}$)
17	Cloudy and high wind	Starts at 8h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 11\%$	23.82 Fig. 4. 35	9.46	26.82 Fig. 4. 36	10.65	46.35 Fig. 4. 37	18.40	166.69 Fig. 4. 38	*66.18*	251.89 Fig. 4. *5*	13.66 ($Cost_{MPC}$) 0.74 ($Cost_{MPC}^{BSS}$)
18	Cloudy and low wind	Starts at 8h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 55\%$	78.39 Fig. 4. 39	31.12	78.39 Fig. 4. 39	31.12	98.79 Fig. 4. 40	39.22	166.69 Fig. 4. 38	*66.18*	251.89 Fig. 4. *5*	1.39 ($Cost_{MPC}$) 0.59 ($Cost_{MPC}^{BSS}$)
19	Cloudy and high wind	Starts at 22h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$	28.41 Fig. 4. 41	11.28	28.41 Fig. 4. 41	11.28	46.35	18.40	166.69	*66.18*	251.89	55.88 ($Cost_{MPC}$) 0.63 ($Cost_{MPC}^{BSS}$)
20	Cloudy and low wind	Starts at 22h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 55\%$	80.41 Fig. 4. 42	31.92	80.41 Fig. 4. 42	31.92	98.79	39.22	166.69	*66.18*	251.89	3.16 ($Cost_{MPC}$) 0.65 ($Cost_{MPC}^{BSS}$)
21	Cloudy and high wind	Starts at 4h $SOC_{bat}^{ini} = 90\%$ $SOC_{H2}^{ini} = 100\%$	29.40 Fig. 4. 43	11.67	29.40 Fig. 4. 43	11.67	46.35	18.40	166.69	*66.18*	251.89	122.56($Cost_{MPC}$) 0.62 ($Cost_{MPC}^{BSS}$)
22	Cloudy and high wind	Starts at 4h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 55\%$	25.21 Fig. 4. 44	10.01	28.83 Fig. 4. 45	11.45	46.35	18.40	166.69	*66.18*	251.89	13.65 ($Cost_{MPC}$) 1.16 ($Cost_{MPC}^{BSS}$)
23	Cloudy and high wind	Starts at 4h $SOC_{bat}^{ini} = 55\%$ $SOC_{H2}^{ini} = 11\%$	27.01 Fig. 4. 46	10.72	29.68 Fig. 4. 47	11.78	46.35	18.40	166.69	*66.18*	251.89	8.69 ($Cost_{MPC}$) 0.93 ($Cost_{MPC}^{BSS}$)
24	Cloudy and low wind	Starts at 4h $SOC_{bat}^{ini} = 75\%$ $SOC_{H2}^{ini} = 55\%$	79.06 Fig. 4. 48	31.39	79.42 Fig. 4. 49	31.53	98.79	39.22	166.69	*66.18*	251.89	2.15 ($Cost_{MPC}$) 0.75 ($Cost_{MPC}^{BSS}$)