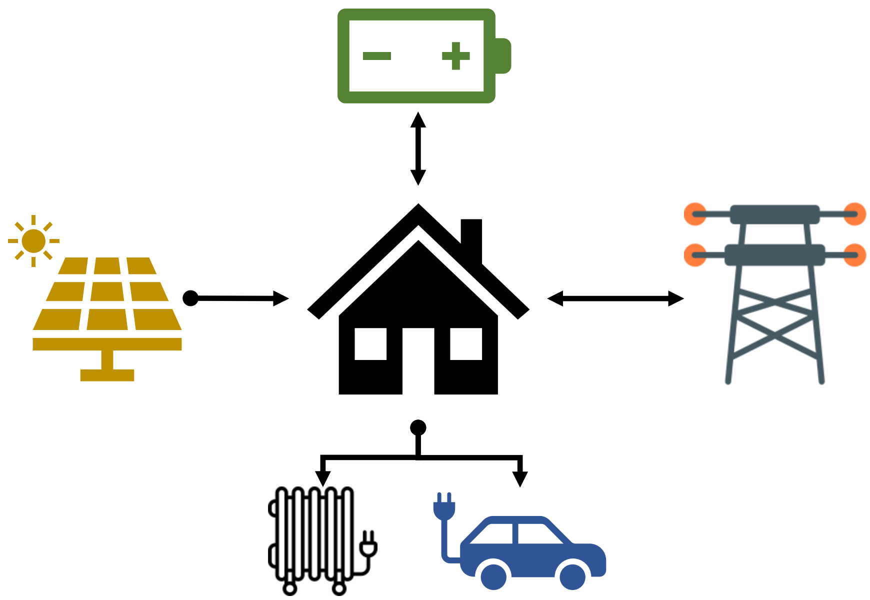
Residential Battery Management Tool (RBMT)

Version 1.5 (2022)



This tool was validated and detailed in the following paper: '[Domestic Battery Power Management Strategies to Maximize the Profitability and Support the Network]()', authored by Ahmed A.Raouf Mohamed, Robert J. Best, Xueqin Liu, and D. John Morrow presented at the IEEE PES General Meeting 2021.

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1. Introduction:

Behind the meter battery energy storage systems are attracting more customers due to their ability to achieve a profitable energy arbitrage in the presence of heat-pumps, electric vehicles (EV) and solar photovoltaics (PV) with time of use tariffs. From the distribution system operator's perspective, these units can be utilized to support the network, especially with the rapid deployment of microgeneration and the electrification of transportation and heat. This code contains three different management strategies for the residential behind the meter battery energy storage systems (BESS) to maximize the customer's profitability and enhance the network performance.

The three algorithms are briefly explained as:

1- Conventional Rule-Based Algorithm (CRBA): This is the conventional method of (dis)charging the BESS according to upper and lower thresholds that maximizes the customers profitability only through maximizing the PV self-consumption.
2- Proposed Day-Ahead Scheduling Algorithm (PDSA): This is an optimization-based algorithm aims to optimize the electricity bill and load variance using the WORHP solver. Optimizing the load variance supports the network through flattening the household net profile.
3- Proposed Rule-Based Algorithm (PRBA): This is a rule-based algorithm that does not require any optimizer however, it optimizes the electricity bill and load variance according to a set of inputs.

This tool can be used to generate the power dispatch of residential batteries (with any specifications) to minimize the household's electricity bill for any time series data (single day to multiple years) with any temporal resolution. The outputs of the RBMT are:

1. The net household demand with and without the battery.
2. Electricity bill with and without the battery.
3. Battery power dispatch.
4. Battery state of charge.
5. Battery degradation.
6. Household's voltage.
7. Household's losses.
8. PV self-consumption
9. Self-sufficiency
10. Exported energy
11. Curtailed energy

Two plots are developed after the program converges: 1) the net demand with the battery state of charge; 2) the battery degradation.

2. Guide:

The tool has two MATLAB files and two excel/csv file, described as:

RBMT.m	Used to enter the tool inputs and run the tool.
MAINCODE.m	Main file contains the algorithms.
Inputs.csv *(v 1.4)*	Used to enter the time-series profiles of household demand, PV, and EV.
Results.xls	Excel template for the results. Results are saved in this file.

In order to run the code, the required inputs are detailed as follows:

- The household profiles should be entered in any data resolution in the file (Inputs.csv) in the following format:

Demand (kW) (first column)	PV (kW) (second column)	EV (kW) (third column)

  - All values should be positive. To add measurements of a heat pump or any other loads, please add their values to the demand (sum) in first column or to the EV third column.

- Use RBMT.m, to run the code. The inputs for the (RBMT.m) are described in the following table:

Main Inputs	
`SaveR`	To save the data in excel sheet: 1 will save in Results.xls, other values will not
`Prog`	Selects the required algorithm: 1 for CRBA, 2 for PDSA, and 3 for PRBA
`DataRes`	Data resolution in minutes: 10 for 10 minutes, 30 for 30 minutes, 60 for 1 hour
BESS Inputs	
`BESS`	Actual Battery Capacity [kWh]
`DOD`	Maximum depth of discharge in fraction (0 to 1)
`SOCMAX`	Maximum state of charge (0 to 1)
`BESSP`	Maximum rating of the BESS [kW]
`RE`	BESS System efficiency = BESS Efficiency ($\sqrt{roundtrip\ efficency}$) $\times$ Inverter/Charger Efficiency
`SOCI` *(v 1.1)*	Initial value of SOC that the simulations will start with, default=minimum SOC
Utility Inputs- Time of use tariff (The algorithms are developed for the double tariff rates, UK)	
`EXP` *(v 1.5)*	Export power limit [kW]
`SC` *(v 1.3)*	Standing charge [p/day]
`HR`	High-rate value (day rate) [p/kWh]
`LR`	Low-rate value (night rate) [p/kWh]
`TLS`	Start hour of low-rate tariff
`TLE`	End hour of low-rate tariff
`EX`	Export tariff rate in [p/kWh]
`TPR`	Tariff daily profile, please insert the values of high rate (HR) and low rate (LR) at each hour according to your preference.
Network Details to calculate the losses and household voltage	
`VT`	Network Transformer voltage [V]
`PF`	Power factor
`R`	Resistance from the transformer to the household [Ohm]
`X`	Reactance from the transformer to the household [Ohm]
Program 1 (CRBA) Inputs	
`PTHD`	Upper threshold for discharging [kW]
`PTHC`	Lower threshold for charging [kW]
`PCN` *(v 1.2)*	A percentage of the BESS capacity to be charged using low tariff rate. Default = 0 (no charging during the low tariff period). It can be entered as a single value or different values for each day.
`ETOC` *(v 1.2)*	End overnight charging time (in hours); Default=0 if you do not want to charge the battery overnight
`DIA` *(v 1.2)*	An option to allow the battery to discharge after the end of low tariff period (`DIA=1`), or to discharge the battery whenever the demand exceeds the generation at any time of the day (`DIA=0`);
Program 3 (PRBA) Inputs	
`EVS`	EV charger rating [kW]
`AVGD`	Average daily consumption [kWh]
`Season`	The PV seasons (1 for high PV season / summer, 0 for low PV season / winter)
`PTHDn`	Normal upper threshold for discharging [kW]
`EVA`	Average EV charging hours

EVC	Electric vehicle status, if the EV will be charged next day EVC=1, otherwise, EVC=0
FPV	Forecasted PV daily generation
PVL	Forecasted of number of PV hours calculated from the start time of PV (PVS) and the end time of PV (PVe)

- To use the PDSA, the WORHP solver require to be installed in your machine. You can download the solver and request the License from this Link: https://worhp.de/. After the installation completes according to the WORHP guide, please copy the license file (worhp.lic) and the XML file (worhp.xml) to this folder or add it to the MATLAB directory.
- The electricity and export tariffs are entered in British pence / kWh. However, it can be changed to different currency according to the country regulations and tariff structures.
- More details on the work implemented in this code is available in a published paper (see citation [1]).

3. Download and licensing:

The RBMT is available for free download from (https://github.com/ARa2of/Behind-the-Meter-BESS-Management-Strategies-). This open-source simulation tool is published under the MIT-License.

4. Citation:

- Please acknowledge any contributions of the RBMT by citing:
  [1]. A. A. R. Mohamed, R. J. Best, X. Liu and D. J. Morrow, "Domestic Battery Power Management Strategies to Maximize the Profitability and Support the Network," 2021 IEEE Power & Energy Society General Meeting (PESGM), 2021, pp. 1-5, doi: 10.1109/PESGM46819.2021.9638038.

- If you used the optimization-based algorithm (PDSA), please cite the following paper in addition to [1]:
  [3]. C. Büskens and D. Wassel, 'The esa nlp solver worhp', in Modeling and optimization in space engineering, Springer, 2012, pp. 85–110

The RBMT utilizes the following BESS degradation model and rainflow algorithm:

[4]. B. Xu, A. Oudalov, A. Ulbig, G. Andersson and D. S. Kirschen, "Modeling of Lithium-Ion Battery Degradation for Cell Life Assessment," in IEEE Transactions on Smart Grid, vol. 9, no. 2, pp. 1131-1140, March 2018, doi: 10.1109/TSG.2016.2578950

[5]. ASTM E1049-85: 'Standard Practices for Cycle Counting in Fatigue Analysis', ASTM International, West Conshohocken, 2017

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