Analysis of Economic Viability of Vehicle-to-Grid Service by Plug-In Electric Vehicles for Varied Depth-of-Discharge in Microgrid Markets

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Research Problem

Participation of Plug-in-Electric Vehicles (PEVs) offering Grid-to-Vehicle(G2V) and Vehicle-to-Grid(V2G) services in Demand Response programs in a microgrid aid in reducing the supply-demand mismatch thereby promoting renewable energy sources. The frequent charge and discharge cycles of PEVs in microgrids due to V2G service is associated with cost of degradation of battery that necessitates the economic viability analysis under various electricity market scenarios.

Goals

- Optimal scheduling of charging and discharging of PEVs in a microgrid with inclusion of BDC into consideration to reduce the energy mismatches.
- Economic viability analysis of V2G service with BDC incorporation for different Depth-of-Discharge (DOD) values in the context of competitive electricity markets of a micro-grid.

Economic Modelling

$$BDC = \left(\frac{1}{f(D_j)} - \frac{1}{f(D_{j-1})}\right) * CB \text{ where } f(D_j) = 10^{N(Dj)}$$

$$Revenue_{per\ cycle} = (MCP_{discharge} - MCP_{charge}) * PEVratedkW * DI_{duration}$$

$$Profit_{per\ cycle} = (MCP_{discharge} - MCP_{charge}) * PEV\ ratedkW * DI_{duration} - BDC$$

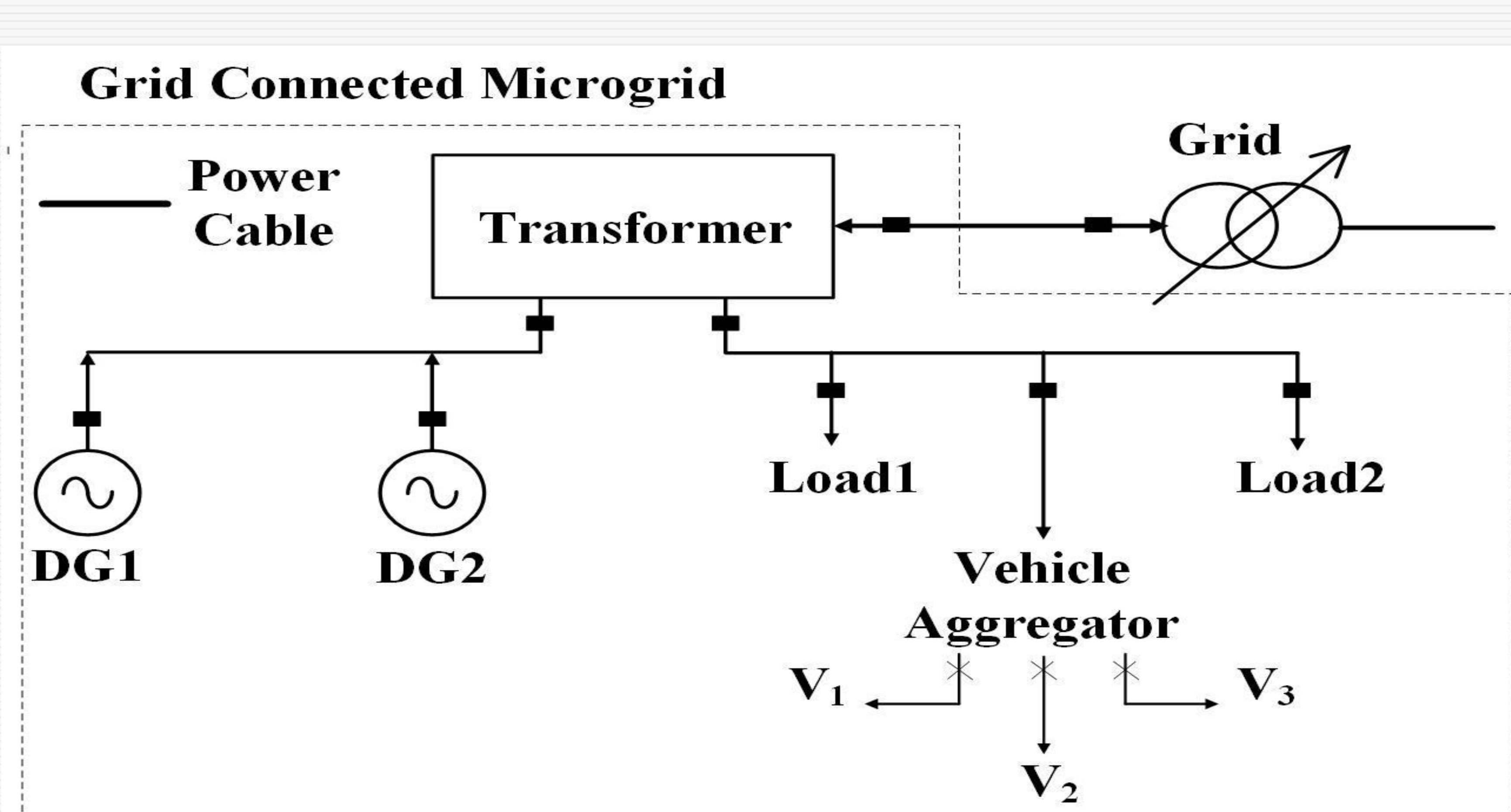
$$Total_{Revenue} = (\sum MCP_{discharge} - \sum MCP_{charge}) * PEV\ ratedkW * DI_{duration}$$

Objective 1: Min $\sum_{j=1}^{N} (\sum P_{Gj} - \sum P_{Lj} + \sum a_{kj} * P_{PEVkj})$

Objective 2: Min $\sum_{j=1}^{N} (MCP_{0j} * \sum b_{kj} * P_{PEVkj} - MCP_{1j} * \sum b_{kj} * P_{PEVkj} + BDC)$

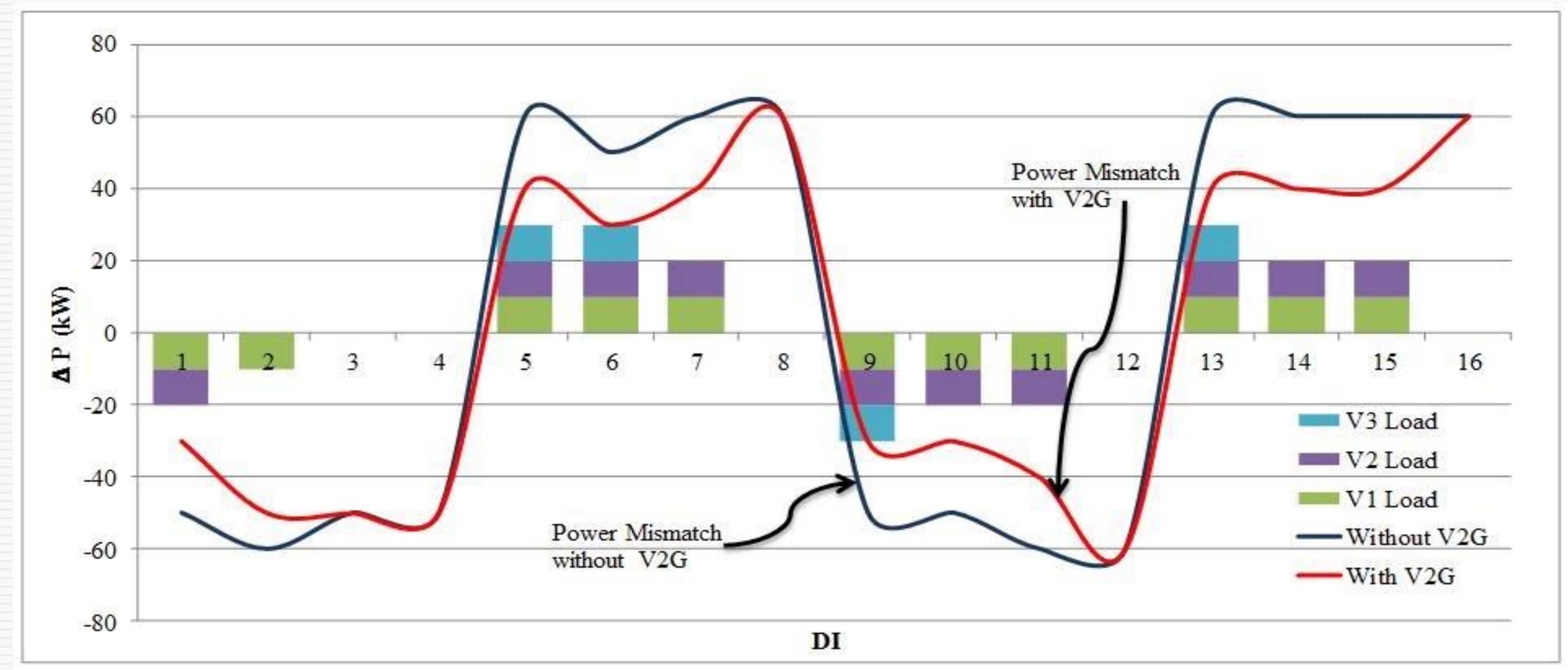
where D_j and D_{j-1} represent DOD in interval 'j' and 'j-1'; $N(D_j)$ and $N(D_{j-1})$ are the number of life-cycles on log-scale for corresponding DOD; CB is the cost of battery; DI is the demand interval; N is the total number of intervals; $\sum P_{Gj}$ is the total generation in kW in interval 'j'; $\sum P_{Lj}$ is the total load in kW in interval 'j'; P_{PEV} is the rating of *k*th PEV, MCP_{0j} is the price for charging the PEV in interval 'j', MCP_{1j} is the price associated with discharging of PEV in interval 'j'; a_{kj} and b_{kj} are decision variables for '*k*'th PEV in interval 'j' (0 or (+/-) 1).

Case Study: Microgrid system with PEVs as Responsive loads

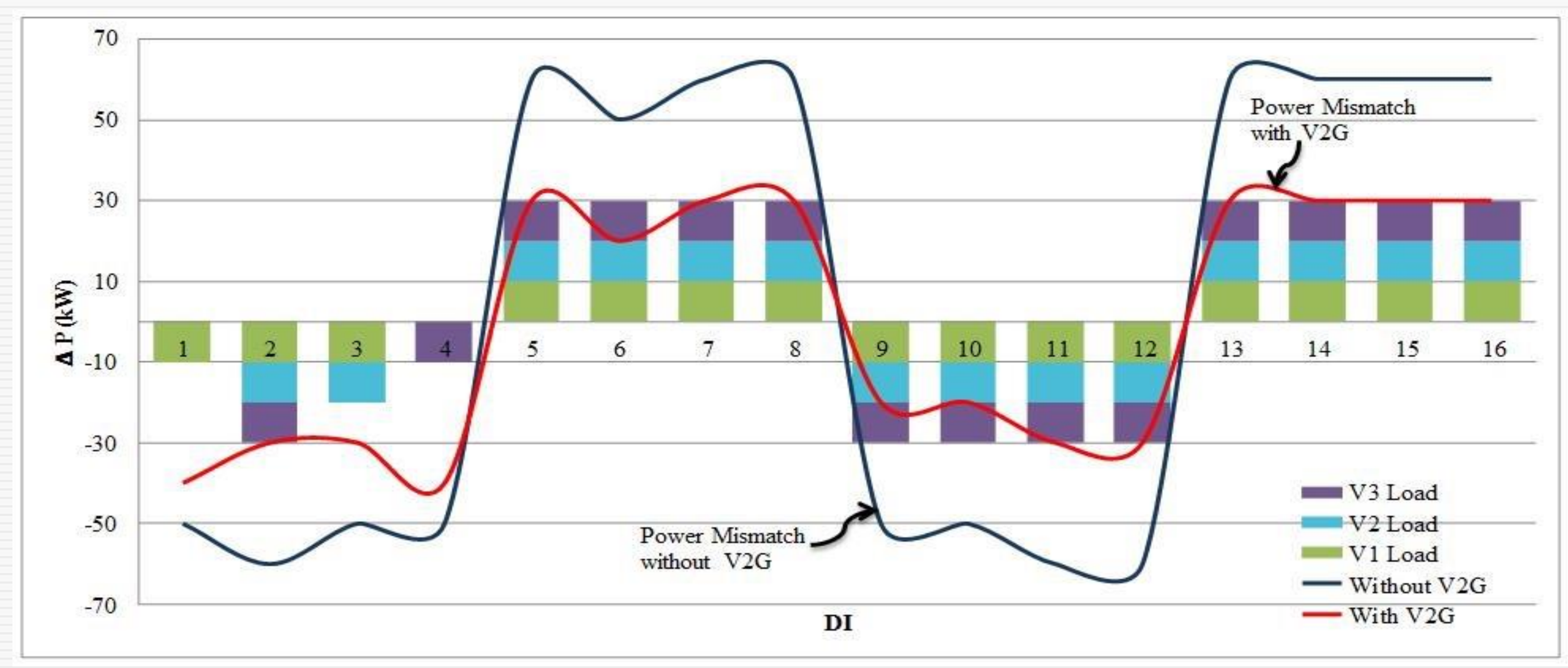


Ratings: DGs - 100kW ; Loads-100kW; PEVs: +10kW (charging) and 10kW(discharging)

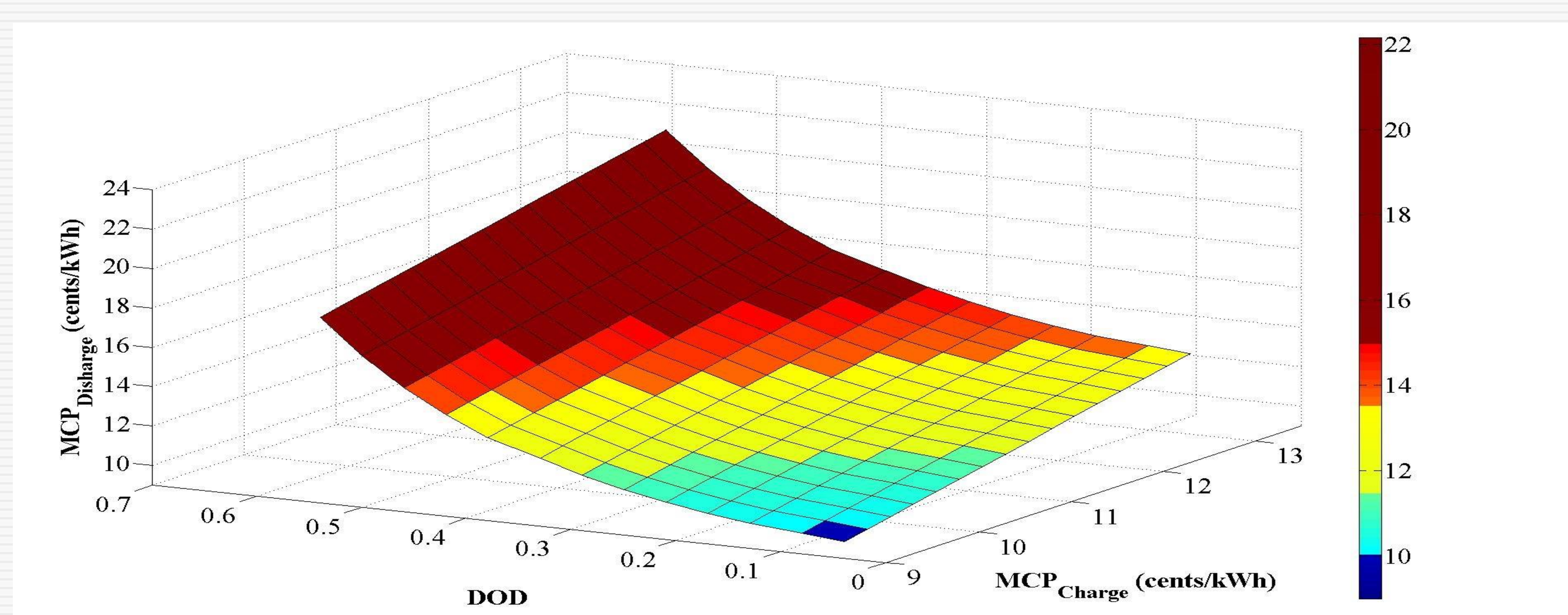
Scheduling of V2G load with DR participation without forecast



Scheduling of V2G load with DR participation with forecast



DOD vs. MCP_{Charge} vs. $MCP_{Discharge}$: Feasibility ranges



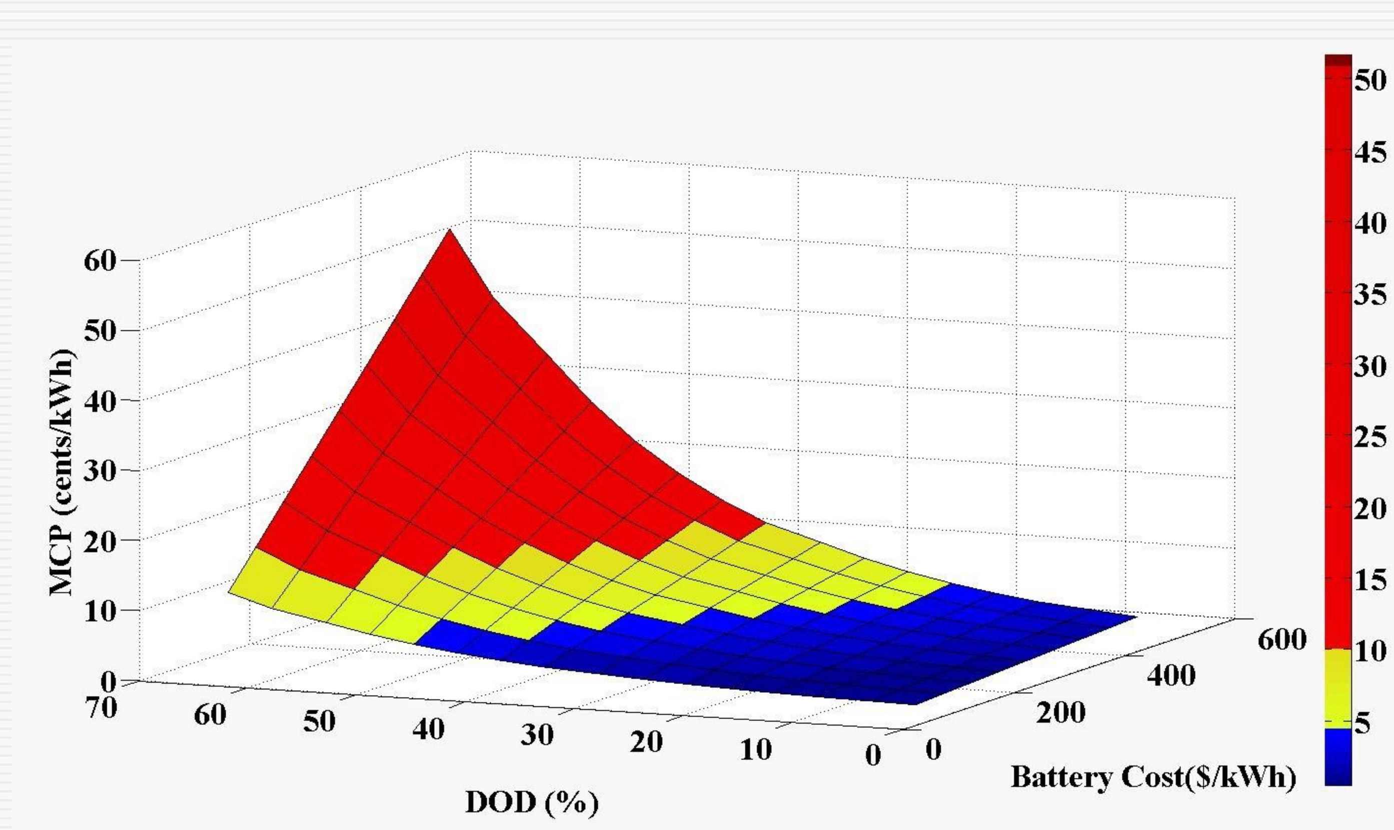
Blue region:
MCP_{Charge} range (9 ¢,10.25 ¢)
$MCP_{Discharge}$ range (9.84 ¢,11.25 ¢)

Red region:
MCP_{Charge} range (9 ¢,12.5 ¢)
$MCP_{Discharge}$ range (13.5 ¢,15 ¢)

Yellow region:
MCP_{Charge} range (9 ¢,12.5 ¢)
$MCP_{Discharge}$ range (11.25 ¢,13.5 ¢)

Maroon region:
MCP_{Charge} range (9 ¢,12.5 ¢)
$MCP_{Discharge}$ ≥ 15 ¢.

%DOD vs. Battery Cost vs. ΔMCP: Feasibility Ranges



Blue region:
ΔMCP ≤ 4.5 ¢

Yellow region:
ΔMCP range (4.5 ¢,10 ¢)

Red region:
ΔMCP ≥ 10 ¢

Conclusions

- Favorable conditions for V2G service include availability of forecast information, large variations in ΔMCP or supply-demand mismatch present in the microgrid, higher range of the utility energy prices, higher initial SOC or lesser DOD and low battery cost.

ACKNOWLEDGMENT

The work is supported by National Centre for Photovoltaic Research and Education (NCPRE), funded by Ministry of New and Renewable Energy (MNRE), Government of India.