International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
IJISAE
ISSN:2147-6799 www.ijisae.org Original Research Paper

Technical and Economic Analysis of PV Integrated DC and AC in Front of the Meter System for Automated and Manual Dispatch Modes

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Submitted:13/03/2024 **Revised**: 28/04/2024 **Accepted**: 05/05/2024

Abstract*:* Front-of-the-meter (FOM) based PV system is helpful in adding flexibility to distribution networks for locally generating renewable energy to decarbonise the environment from the impacts of power generation sector. Presently FOM systems are used for specific services at distribution level but for applications in industry these are under development. In this paper a techno-economic analysis of front-of-the-meter systems in primary networks with PV system is presented that covers (i) impact of battery storage systems types (ii) the in terms of different dispatch scheme; and (iii) the quantification for AC and DC connected schemes that give profitability based on techno economic analysis point of view. The analysis performed for grid-level battery energy storage technology particularized to weather data and electric tariff rates followed in Lucknow U.P,India. The techno-economic analysis is covering one year time duration with 30 minute resolution executed at System Advisor Model (SAM) tool. The results are showing that, the techno economic benefits of FOM systems are better than traditional transmission-level services. Several approaches are observed for improving systems profitability.

Keywords: *Flexibility services,Front of meter systems, Li ion battery, Power dispatch, solar energy*

1. Introduction

This Solar photovoltaic (PV) technology contributing largest power compared to different renewable energy technologies like wind/hydro [1]. PV technology growth electric distribution has more demand than other renewable energy resource [2]. The PV systems integration in power distribution networks helping in decarbonising the power systems. However, the variability and intermittency of solar energy are facing technical challenges in terms of power quality and output and put limits on acceptability of PV based power resources. The intermittency and variability PV systems mitigated with distributed storage systems, that helps in reducing renewable energy curtailment and supports stable operation at low-inertia power systems, from microgrids to large systems, with high shares of non-synchronous variable renewable generation [3]. Battery energy storage systems (BESS) has highest applicability in electric distribution networks due to: (i) small time-scales requirement of few hours; (ii) large power range and (iii) large available range of energy capacity [4]. BESS are connected to grid at larger scale (centralised) or at small scale consumer end only (decentralised). Decentralised systems storage are generally behind-the-meter PV solar systems based having battery at consumer end, in terms of increasing self-consumption for obtaining a reduction in utility-bought energy, charges are planned according to demand and financial return are generated from services of grid [5]–[7]. In multiple literatures it is shown that obtained profit mainly depending upon incentives, tariffs and schemes [5], [6], [8], [9], [34].Grid services gives provision for consumer with limited benefits due to shortage of generated power.

The paper presents a multi-level analysis for the integration of a BESS with high PV generation for front of the meter system. The scope covers the above mentioned issues and challenges with focus on specific services with BESS that helps in enabling flexibility and add value. The techno economic analysis presented multiple aspects of grid-integrated BESS and PV systems with front of meter DC/AC connected schemes that are rarely covered together in literature with methodological contribution. The techno economic analysis is including the analysis of different types of batteries used under different energy dispatch management schemes. The assessment moves into AC/DC connected Front of meter system assessment on looking at: (i) effect in cost parameters; (ii) role inverters (iii) provision of flexibility through power supply mode and (iv) economic revenue under present day energy markets.

The contributions of this research work are:

• A technoeconomic analysis on system advisor model (SAM) software for PV integrated BESS based front of meter system.

• The evaluation of performance for different type of battery integrated to PV integrated power supply system impact on low level power system infrastructure,

• The estimation of different power dispatch control schemes for AC as well as DC connected system.

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• The exploration of response in terms of financial returns for weather data collected for Lucknow, India for an isolated 5KW power supply system.

The paper structure is describes as: Section II related work and section III covers description of the methodology used under the research work under mathematical approach, data sources and electric network design. In Section IV, present the technical and economic response analysis generated using SAM software for front of meter system. Section V discusses the conclusion and future scopes.

2. Related Works

Utility grid energy storage focus on large storage in medium-voltage (MV) distribution network serve in mitigating the constraints derived due to distributed generation. Grid supported energy storage useful in stabilizing the power networks through management of grid demand for power quality applications, centralized supply of energy or ancillary services [4]. On comparing with storage in decentralized system, distribution network with centralized storage systems are representing cost-effective solution to plan the distribution for long time duration [10]. Such systems help in minimizing losses, power lines thermal load, fluctuations of voltage, and enhance reliable operations under power transmission [11], [12]. Grid systems are potentially favorable in economical terms as compared to smaller-level microgrid due to the possibility of providing services to grid in electricity markets [13]. Such systems have high cost of drives and require optimization with respect to location and capacity under sizing problem of BESS to configure the batteries operation [4].

The grid associated BESS based distribution networks support PV response. Using the PV structures the location and sizing decision affects performance and act as a characteristic of the network. As an optimization problem, the siting and sizing problem is resolved under mathematical programming like linear programming [14], heuristic method [11] analytical methods or as exhaustive search [15]. These methods require various parameters & technical characteristics as input for modeling the system that is responding to proposed optimization response. A current literature review is indicating focus on topic for optimization approach application for searching technical parameters of power transmission system or storage system, at distribution/transmission level to fulfill economic considerations on addressing siting as well as sizing of centralized BESS [4], [14]. Another consideration is related to applications or services that are provided by BESS, which typically classify power or energy applications for specific application [16]. For example, analysis of BESS optimal location for primary and secondary distribution networks is performed to reduce the energy purchase cost in distribution substation [14].

Economic benefit also considered for services offered by grid and economic benefit as well as substantial value provide by BESS are not recognized in current distribution systems design standards [12]. Services under the traditional methods of generation and transmission services (like frequency/voltage regulation of transmission system level or whole-sale of electricity) under large-scale BESS in dealing with transient at penetrations of high renewable energy [17]. However, distributed generation with PV located mostly at distribution network level. Hence, BESS deployment for mitigation of technical aspects by DG need consideration of revenue from specific distribution services, that are reflecting the value as well as benefit of BESS. Yet, the distribution level based services are rarely flourished. In Northern Ireland, services at distribution level provide real power flexibility has started and passed through testing phase by local network distribution operator under trials in November2022 [18]. Analysis and research focusing centralized BESS at distribution level explore provision for ancillary services for supply of real power with consideration of voltage control, power leveling and multiple ancillary services stacking systems (example energy arbitrage and frequency regulation) in MV range [19,20,21] and under LV networks (example energy arbitrage, voltage regulation, and peak shaving) [22]. However voltage regulation used for supplying reactive power for distribution networks, it is generally ignored in economic analysis in the literature. Generally most of the literature focused on technical benefits, the economic viability of distributed BESS is limited [19], [22], [23]. Yet some literature described positive impacts of BESS in distributed system [14] with transmission services that may give profitability [21] or marginal economic compensation [24]. Literature survey focus on BESS shows a gap and defines for need of development of distribution system services under electrical power generation. Consideration of integrated PV systems for modern grid with voltage regulators, BESS or transformers is not sufficient. Solar radiation as input, PV power output, changes on variations in irradiance and cloud coverage. Thus, integration of studies based on PV requires temporal data of large size and high resolution for estimation of capacity of PV based system impact on power distribution. The dataset availability of high resolution is limited and it requires intensive computation. Simulations with 1to 20 seconds time steps are considered for adequate capturing of response of equipment like transformer, voltage regulators, load devices etc [25]. Advanced studies of PV systems not be limited in assessment for small duration of days, week or month but full-year data requires deep understanding of response and impact of associated equipment [25], [26]. Consideration of integration of PV systems in distribution networks plan requires risk analysis & reliability for supporting islanding behavior of micro-grids. The PV inverter technologies developments also evolved control algorithms implementation. Smart controls of PV inverter for constant Volt-Watt , power factor or Volt-Varis investigated in enabling high capacities PV systems. PV inverters with 1-phase shows improvement in voltage profiles of low voltage distribution systems using reactive power controller [27].Analysis on effect of smart control algorithms for inverter and behind-the-meter energy storage system with PV systems shows enhanced penetration of PV [28]. The effect of smart inverters in grid with centralized battery storage requires investigation for cases of PV integration.

3. Methodology

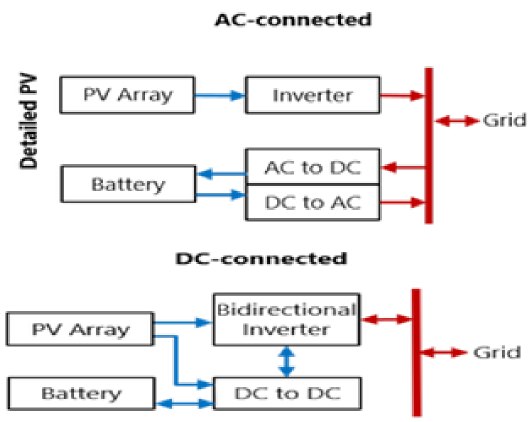

Figure1: Front-of- meter Battery Configurations.

Environmental concerns, advances in technology and consumer demand driving the electric power supply system to next stage. These changes require use of renewable energy to achieve zero emissions. Traditionally electricity supply systems are built and controlled by government authorities and operated as centralized supply to maintain reliable supply and effective cost. The increasing demand of electricity in all aspect of life has challenged all the power system policies and creating financial as well as technical issues.

3.1. Front of Meter system

The alternative that is established is 'behind the meter' integrated with PV connection system for householders and businesses to reduce conventional energy supply cost. Another popular alternative is use of 'front of the meter' connection that shares the locally generated energy to the grid.

The day by day reduction of feed-in-tariffs the solar based users are unable to get fair price for homegrown electricity. The power supply network operators also facing issues of managing technical impacts of wind and solar PV under the business model.

Micro grids that are sharing with solar PV and battery storage producing opportunities to manage the risks in due to changes in electricity sector. For customers, potential benefits include access to wholesale pricing and retail tariffs. The lower costs may also be attained by local control and load management, if peak demand is reduced. The 'in front of the meter' system requires understanding of the technology and fundamental principles of demand/supply. The front-of-meter assumes that battery used to maximize revenue to power generation . The battery in front-of-meter is connected either to the AC or DC side of the inverter as shown in Figure 1.

3.2. SAM system simulation

System Advisor model (SAM) is software used for development demonstration, research and deployment of energy supply systems by integrating weather data, component, and parameters defined under different organizations (eg. National Renewable Energy Laboratory (NREL), Sandia Laboratories, University of Wisconsin and California Energy Commission, U.S. Department of Energy etc) [29]. The SAM software is developed by NREL that is consisting of several models to calculate power output under different technologies of photovoltaic system to find the financial models in terms of net present value, payback period etc. Many research contribution study, work and models using SAM software [30].

The SAM helps solar stakeholders to estimate cost & performance of PV based model. It covers renewable energy resources that incorporate modules to estimate performance Photovoltaic integrated energy systems with specified design parameters and weather data (eg. irradiance, temperature, humidity etc) of desired location available at https://www.nrel.gov. It is incorporating algorithms for estimation of levelized cost of electricity (LCOE) for selection of financial assumptions that is including operational & installation cost. In this paper the analysis investigates the Mono-Si PV cell technology. Mono-Si PV technology is deployed widely in commercial plan that involve large grid PV plant [31], [32].

The simulations in SAM, executed under inputs related to: (1) hourly weather data records (2) PV modules[33], inverters[34], array and battery parameter information; (3) effects of soiling; (4) effects of shading ; and (5) AC/DC based electrical losses[35].

3.3. Solar and weather data

The weather data downloaded from NREL website for location specified for Lucknow, India. It requires information in terms of latitude, longitude and time span. The dataset include time series value of Direct Normal Irradiance (DNI), Global Horizontal Irradiance (GHI) and Diffuse Horizontal Irradiance (DHI). SAM software calculates DHI using sun position by consideration of site's latitude and longitude. The Perez model of Diffuse Sky is used for determining the Plane-of Array (POA) irradiance.

3.4. System Power Flow

Table 1. System design parameters

(a) Location: Lucknow	
Latitude	26.15
Longitude	79.05
(b) Module database	
SunPower	SPR-X21-335
Pmax	335W
Vmax, Voc	57V,70V
Imax, Isc	5.8A,6.2A
Rows in array	1
Column in array	10
Material	Mono-c-Si
Area	1.631m-2
Number of cells	96
(c) Inverter Database	
Solar Edge technologies Ltd	SE6000HUS(208V)
Max AC/DC power	5054/5108 W
Nominal AC/DC voltage	208/480V
Max DC current	13 A
Number of Inverter	1
DC to AC ratio	0.93
(d) System Design	
DC capacity	4.693 KW
AC capacity	5.054 KW
Number of modules	14
Number of strings	2
Total module area	22.834 m2
Module per string in sub array	7
String VOC	475V
String VMP	401V
Maximum DC voltage	480V
(e) Battery Cell & System	
Desired Bank power	5KW
Number of cell in series	3
Number of strings in parallel	1
Battery Bank voltage	50.4 V
Maximum charge current	98.6 A
DC to DC conversion efficiency	99%

Table 2. Electricity rates

Period	Tier	Max.Usage (KWh)	Buy($/kWh)
1	1	0 to 150	0.067
1	2	150 to 300	0.073
1	3	Above 300	0.08

(a) Power Flow during Discharge from Battery

The battery management system (BMS) works prior to inverter for efficient control of battery voltage and the power from PV system as the inverter input that maps the impedance of system [11-12]. The power discharge as Battery output is:

$Power_{battery\_dc} = Power_{battery\_pre\_bms\_dc} * \eta_{BMS}$ (1)

The battery power and PV system power is added as:

$Power_{dc} = Power_{pv\_dc} + Power_{battery\_dc}$ (2)

η = Denote the efficiency.BMS follows following rules:

a) If charge voltage is high the controls applies to lower down it to match with battery voltage.

b) Protects from deep discharge condition

(c) Balance the discharge rate to constant level in presence of solar Photovoltaic voltage.

Output power shared by inverter depends on added power inverter input. Inverter model considers total AC power, inverter and losses due to AC power capacity limitation and other losses.The PV output power split into:

i) AC power produced by PV array

$Power_{pv} = Power_{pv\_dc} * \eta_{inverter}$ (3)

ii) The AC power discharged from battery:

$Power_{battery} = Power_{battery\_dc} * \eta_{inverter}$ (4)

The model is designed supply PV power to load first and remaining excess power supplied to grid. Power supplied to battery if any load is not served.

$P_{battery\_to\_load} = \min (P_{battery}, P_{load} - P_{pv\_to\_load})$ (5) Excess power generated passed to grid as:

$P_{battery\_to\_grid} = P_{battery} - P_{battery\_to\_load}$ (6)

If load require more power than generated by solar photovoltaic, then it is taken by grid

$P_{grid\_to\_load} = P_{load} - P_{pv\_to\_load} - P_{batter\_to\_load}$ (7)

(b) Power Flow- Battery Charging-

Battery storage charging power is defined as:

$P_{battery\_dc} = P_{battery\_pre\_bms} / \eta_{BMS}$ (8)

Charging stage calculation is complex,PV generated energy is used for charging and handling load. In the PV connected DC storage battery system, the battery charging performed by PV without AC conversion and excess PV passed to inverter.

$P_{pv\_inverter\_dc} = P_{pv\_dc} - P_{pv\_to\_battery}$ (9)

When PV power is low it charge the battery and extra power supplied by grid:

$P_{Grid\_to\_battery\_dc} = Abs(P_{battery\_dc}) - P_{PV\_to\_battery}$ (10)

DC power passing through inverter considers single waypower flow calculated as:

$$P_{dc}=P_{pv\_inverter}-P_{Grid\_to\_battery\_dc} \quad (11)$$

The DC power passed through inverter produces AC power and calculated as:

$$P_{pv}=P_{pv\_inverter\_dc}*\eta_{inverter} \quad (12)$$

AC power components calculated by disintegrating total AC power as:

$$P_{grid\_to\_battery}=P_{grid\_to\_battery\_dc}/\eta_{inverter} \quad (13)$$

Further calculations are similar for discharging mode, only a special case is added for power flow from battery towards load and from battery to grid are considered to be zero.

4. Results

The PV and BESS based Front of Meter system designed of SAM software for 5KW load demand. The system equipment parameters in terms of PV module, inverter, Battery bank are shown in Table 1. The electricity rates as the tarrif are taken from the rates declared by Madhyanchal Vidhyut Nigam Ltd (MVNL) for residential customer and shown in Table 2.

4.1. Battery Types

A short description of six different battery types is used in this research analysis are:

(1) LMO/Graphite: Lithium Manganese Oxide (LiMn2O4, inexpensive high-voltage cathode material, high power capabilities, low lifespan.

(2) LFP/Graphite: Lithium Iron Phosphate (LiFePO4), low voltage cathode material, safety properties, low volumetric energy.

(3) LCO/Graphite: Lithium Cobalt Oxide ($LiCoO_2$), common cathode material, high specific energy, costly and toxic.

(4) LMO/LTO: Lithium Titanate ($Li_4Ti_5O_{12}$), promising anode material, excellent lifetime, low specific capacity & high cost.

5) NMC/Graphite: Nickel Manganese Cobalt ($LiNiMnCoO_2$), less expensive cathode material, improved safety characteristics.

(6) NCA/Graphite: Nickel Cobalt Aluminum (LiNiCoAlO2), similar to NMC as a cathode material, high specific energy [36].

4.2. Dispatch Modes

In this research work following battery dispatch mode are analyzed:

(1) Manual Dispatch

(2) Look ahead from charging by system

(3) Look ahead from charging by system and grid

(4) Look Behind from charging by system

(3) Look Behind from charging by system and grid

Table 3a showing result of execution for FOM system with DC connected design architecture. The performance metrics are Annual AC energy (Year 1), DC capacity factor in Year 1, Energy yield in Year 1, Battery round-trip efficiency, Levelized cost of energy (LCOE), Internal Rate of Return (IRR), Net present value. For each dispatch mode the performance metric values are given for different types of batteries. It may be observed that the yellow highlighted values are best result under each dispatch mode. The annual AC energy (Year 1), DC capacity factor in Year 1, Energy yield in Year 1, Battery round-trip efficiency is always observed to be highest for NCA/GRAPHITE battery type and the Levelized cost of energy (LCOE), Internal Rate of Return (IRR), Net present value metrics are observed highest for LFP/GRAPHITE battery type for charge from system case and manual dispatch case but for the charge from system and grid case LMO/LTO are giving best result. Table 3b showing result of execution for FOM system with AC connected design architecture. For each dispatch mode the performance metric values are given for different types of batteries. The annual AC energy (Year 1), DC capacity factor in Year 1, Energy yield in Year 1, Battery round-trip efficiency is always observed to be highest for NCA/GRAPHITE battery type and the Levelized cost of energy (LCOE), Internal Rate of Return (IRR), Net present value metrics are observed highest for LFP/GRAPHITE battery type for charge from system case and manual dispatch case but for the charge from system and grid case LMO/LTO are giving best result. Table 4 summarizes the results for AC and DC connected to draw conclusion for overall best system in terms of battery type and dispatch mode.

Table 3 a. Analysis of PV resource based DC connected Front-Of-Meter system

Dispatch Mode:	Battery Type	Annual AC energy (Year 1)	DC capacity factor Year 1	Energy yield in Year 1	Battery round-trip efficiency	Levelized cost of energy LCOE	Internal Rate of Return IRR	Net present value
Automated Dispatch: Perfect Look Ahead Battery can charge from system		kWh	%	kWh/kW	%	Cent/kWh	%	$
	LMO/GRAPHITE	7593	18.5	1618	96.13	8.5	13.79	5625
	LFP/GRAPHITE	7591	18.5	1618	95.21	8.37	14.17	5755
	LCO/GRAPHITE	7591	18.5	1617	94.69	8.65	13.36	5465
	LMO/LTO	7590	18.5	1617	94.77	8.51	13.76	5611
	NMC/GRAPHITE	7591	18.5	1618	94.51	8.64	13.37	5468
	NCA/GRAPHITE	**7595**	**18.5**	**1618**	96.69	8.5	13.8	5627
Automated Dispatch: Perfect Look Ahead Battery charge from Grid & system	LMO/GRAPHI	7514	18.3	1601	94.94	8.06	17.12	6880
	LFP/GRAPHIT	7502	18.2	1599	93.23	7.46	17.48	7635
	LCO/GRAPHIT	7514	18.3	1601	92.09	9.16	13.22	5149
	LMO/LTO	7438	18.1	1585	90.85	**7.39**	**17.61**	**7828**
	NMC/GRAPHI	7364	17.9	1569	87.19	7.65	17.14	7437
	NCA/GRAPHIT	7524	18.3	1603	95.97	8.37	17.01	6495
Automated Dispatch: One Day Look Behind Battery can charge from system	LMO/GRAPHI	7592	18.5	1618	96.14	8.5	13.52	5470
	LFP/GRAPHIT	7591	18.5	1618	95.10	8.37	13.83	5572
	LCO/GRAPHIT	7590	18.5	1617	94.51	8.65	13.06	5281
	LMO/LTO	7590	18.5	1617	94.22	8.51	13.49	5460
	NMC/GRAPHI	7588	18.5	1617	92.97	8.64	13.09	5312
	NCA/GRAPHIT	7593	18.5	1618	**96.71**	8.5	13.52	5457
Automated Dispatch: One Day Look Behind Battery can charge from Grid & system	LMO/GRAPHI	7517	18.3	1602	94.99	8.10	16.46	6531
	LFP/GRAPHIT	7504	18.3	1599	93.24	7.47	16.94	7348
	LCO/GRAPHIT	7514	18.3	1601	92.10	9.12	12.97	5054
	LMO/LTO	7438	18.1	1585	90.80	**7.39**	17.12	7538
	NMC/GRAPHI	7364	17.9	1569	87.19	7.64	16.65	7177
	NCA/GRAPHIT	7526	18.3	1604	95.99	8.38	16.36	6196
Manual Dispatch	LMO/GRAPHI	7581	18.4	1615	95.55	8.51	13.03	5234
	LFP/GRAPHIT	7578	18.4	1615	94.60	8.38	13.46	5375
	LCO/GRAPHIT	7573	18.4	1614	93.93	9.17	12.62	4548
	LMO/LTO	7571	18.4	1613	93.53	8.53	12.99	5183
	NMC/GRAPHI	7562	18.4	1611	91.20	8.68	12.54	5027
	NCA/GRAPHIT	7584	18.4	1616	96.17	8.70	13.05	5039

(*Yellow highlight :Best &Pink highlights: Worst result)

Table 3 b. Analysis of PV resource based AC connected Front-Of-Meter system

Dispatch Mode:	Battery Type	Annual AC energy	DC capacity factor	Energ y yield in	Battery roundtri p	Levelize d cost of energy	Interna l Rate of	Net present value
		kWh	%	kWh/k	%	Cent/k	Years	$
Automated Dispatch:Perfect Look Ahead Battery can charge from system	LMO/GRAPHI	7577	18.4	1615	91.26	8.52	13.73	5589
	LFP/GRAPHIT	7577	18.4	1615	90.24	8.38	14.10	5718
	LCO/GRAPHIT	7573	18.4	1614	89.64	8.67	13.29	5427
	LMO/LTO	7574	18.4	1614	89.68	8.52	13.69	5575
	NMC/GRAPHI	7574	18.4	1614	89.51	8.66	13.3	5431
	NCA/GRAPHI	7578	18.4	1615	**91.93**	8.51	13.73	5588
Automated Dispatch: Perfect Look Ahead Battery can charge from Grid & Charge from system	LMO/GRAPHI	7485	18.2	1595	90.46	8.08	17.10	6842
	LFP/GRAPHIT	7473	18.2	1592	88.61	7.49	17.44	7595
	LCO/GRAPHIT	7489	18.2	1596	87.38	9.11	13.43	5195
	LMO/LTO	7400	18.0	1577	85.99	**7.40**	17.54	7787
	NMC/GRAPHI	7377	17.9	1572	82.80	7.81	16.72	7249
	NCA/GRAPHI	7499	18.2	1598	91.65	8.37	16.99	6489
Automated Dispatch: One Day Look Behind Battery charge from system	LMO/GRAPHI	7583	18.4	1616	91.02	8.51	13.45	5414
	LFP/GRAPHIT	7581	18.4	1616	89.72	8.38	13.77	5529
	LCO/GRAPHIT	7579	18.4	1615	88.87	8.66	12.93	5226
	LMO/LTO	7580	18.4	1615	88.64	8.52	13.46	5441
	NMC/GRAPHI	7577	18.4	1615	87.64	8.66	13.06	5293
	NCA/GRAPHI	**7584**	**18.4**	**1616**	91.85	8.51	13.36	5387
Automated Dispatch: One Day Look Behind Battery charge from Grid &	LMO/GRAPHI	7485	18.2	1595	90.49	8.13	16.44	6501
	LFP/GRAPHIT	7473	18.2	1592	88.61	7.51	16.86	7296
	LCO/GRAPHIT	7490	18.2	1596	87.38	9.13	12.93	5041
	LMO/LTO	7401	18.0	1577	85.99	**7.40**	17.06	7506
	NMC/GRAPHI	7378	17.9	1572	82.80	7.81	16.24	6987
	NCA/GRAPHI	7499	18.2	1598	91.65	8.41	16.35	6155
Manual Dispatch with TOD Multiplier Apply	LMO/GRAPHI	7550	18.4	1609	91.34	8.54	12.91	5174
	LFP/GRAPHIT	7549	18.4	1609	90.58	8.41	13.35	5320
	LCO/GRAPHIT	7542	18.3	1607	89.77	9.2	12.51	4494
	LMO/LTO	7542	18.3	1607	89.52	8.56	12.88	5123
	NMC/GRAPHI	7531	18.3	1605	87.49	8.71	12.43	4967
	NCA/GRAPHI	7522	18.4	1609	91.92	8.74	12.93	4981

(*Yellow highlight :Best result&Pink highlight : Worst result)

Table 4. Comparison for AC and DC connected FOM system

	DC Connected					AC connected				
	Perfect Look Ahead Battery can charge from	Perfect Look Ahead Battery can charge from	One Day Look Behind Battery charge from system	One Day Look Behind Battery charge from Grid &	Manual Dispatc h with TOD Multipli er Apply	Perfect Look Ahead Batter y can charge	Perfect Look Ahead Battery can charge from	One Day Look Behind Battery charge	One Day Look Behind Battery charge from	Manua l Dispat ch with TOD Multip

	system	Grid & Charge from system		system		from system	Grid & Charge from system	from system	Grid & system	lier Apply
Annual AC energy (Year 1)	7595 NCA/ Graphite	7524 NCA/ Graphite	7593 NCA/ Graphite	7526 NCA/ Graphite	7584 NCA/ Graphite	7578 NCA/ Graphite	7499 NCA/ Graphite	7584 NCA/ Graphite	7499 NCA/ Graphite	7522 NCA/ Graphite
DC capacity factor Year 1	18.5 NCA/ Graphite	18.3 NCA/ Graphite	18.5 NCA/ Graphite	18.3 NCA/ Graphite	18.4 NCA/ Graphite	18.4 NCA/ Graphite	18.2 NCA/ Graphite	18.4 NCA/ Graphite	18.2 NCA/ Graphite	18.4 NCA/ Graphite
Energy yield in Year 1	1618 NCA/ Graphite	1603 NCA/ Graphite	1618 NCA/ Graphite	1604 NCA/ Graphite	1616 NCA/ Graphite	1615 NCA/ Graphite	1598 NCA/ Graphite	1616 NCA/ Graphite	1598 NCA/ Graphite	1609 NCA/ Graphite
Battery roundtrip efficiency	96.69 NCA/ Graphite	95.97 NCA/ Graphite	96.71 NCA/ Graphite	95.99 NCA/ Graphite	96.17 NCA/ Graphite	91.93 NCA/ Graphite	91.65 NCA/ Graphite	91.85 NCA/ Graphite	91.65 NCA/ Graphite	91.92 NCA/ Graphite
Levelized cost of energy LCOE	8.37 LFP/ Graphite	7.39 LMO/ LTO	8.37 LFP/ Graphite	7.39 LMO/ LTO	8.38 LFP/ Graphite	8.38 LFP/ Graphite	7.40 LMO/ LTO	8.38 LFP/ Graphite	7.40 LMO/ LTO	8.41 LFP/ Graphite
Internal Rate of Return IRR	14.17 LFP/ Graphite	17.61 LMO/ LTO	13.83 LFP/ Graphite	17.12 LMO/ LTO	13.46 LFP/ Graphite	14.10 LFP/ Graphite	17.54 LMO/ LTO	13.77 LFP/ Graphite	17.06 LMO/ LTO	13.35 LFP/ Graphite
Net present value	5755 LFP/ Graphite	7828 LMO/ LTO	5572 LFP/ Graphite	7538 LMO/ LTO	5375 LFP/ Graphite	5718 LFP/ Graphite	7787 LMO/ LTO	5529 LFP/ Graphite	7506 LMO/ LTO	5320 LFP/ Graphite

5. Conclusion

In this work research analysis on Photo Voltaic system integrated front of the meter system is simulated on SAM software for techno economic analysis for DC and AC connected system. The performance observation follows for different battery power dispatch mode for different types of battery. The best value is given by LMO/LTO battery type for the LCOE, IRR and Net present value metrics for the DC connected system under Perfect Look Ahead case when battery can charge from Grid & Charge from system. This mode is giving highest annual energy in 12 years for both DC/AC connected front of meter system. However for the metric in terms of Annual**AC** energy (Year 1), DC capacity factor Year 1, Energy yield in Year 1, Battery round-trip efficiency the Li ion battery observed to be NCA/Graphite is best under Perfect Look Ahead Battery can charge from system. The performance of DC connected system is higher than AC connected system.

6. Acknowledgment

The author would like to acknowledge Integral University for providing acknowledgement no. IU/R&D/2024-MCN0002724.

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