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Sizing of Degradation Based Battery Storage Systems for Operating Cost Minimization in Microgrids

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Abstract: A microgrid is a low voltage distribution network designed to provide power for small scale and isolated communities consisting of distributed generation and Energy Storage Systems .One of the major issues in the isolated microgrids with intermittent nature of distributed generation is the balance of energy demand. This can be achieved by appending renewable energy sources with suitable Battery Energy Storage Systems, to provide the reserve support in meeting the load demand. Battery degradation effect plays a major role in analysing the performance of BESS Life Time. This depends on average kWh and average MWh throughput discharge from BESS. Therefore, microgrid system with BESS considering degradation effect should be optimized in such a way as to obtain minimum operating cost while ensuring minimum electricity cost to customers. This paper presents an optimization algorithm for microgrid operating cost and customer electricity cost minimization for 24hrs time horizon while considering BESS degradation effect by determining kWh and MWh throughput. Particle Swarm Optimization (PSO), Accelerated particle swarm optimization (APSO), Jaya optimization (JAYA) technique and Linear programming interior point algorithm (LP-IP) have been applied to determine the optimal operating cost and electricity cost by simulating BESS degradation parameters.

Keyworks: Battery Energy Storage Systems (BESS), Microgrid, Distributed Generations, Throughputs, Degradation effect, optimization.

I. INTRODUCTION

Microgrid with Energy storage systems has become one of the promising solutions of future smart grid to overcome intermittent nature of Distributed Generations (DGs). Energy Storage Systems (ESS) has a wide range of performance requirements in terms of life time and discharge capacities. The microgrid configuration with ESS can address a variety of applications such as load levelling, renewable matching and meeting end user demand by distributing power to remote and isolated localities, to mitigate load fluctuations and improve power quality [1].BESS are one of the best choices to support the DGs in meeting reliability, as they are the sources of high power and energy densities. In the current scenario, Microgrid operations with Renewable energy sources and BESS are the preferred solutions in the grid and island connected mode to overcome energy crisis [2]. The intermittent nature of DGs can be overcome by using a suitable ESS particularly BESS, due to its high energy and power density. Therefore integration of distributed generations with storage reduces the disadvantage caused by generation of electricity from fuels [3]. This can be achieved by obtaining optimized maximum discharge rates of BESS and DGs within the limits of State of Charge (SoC) and power, the efficiency of the microgrid can be achieved without any limitations in power supply at the end user level [4-5].

Many techniques have been applied in literature to minimize the operating and electricity cost by optimizing the size of BESS in terms of its discharge capacities without considering the degradation effect-based life time .[6-8] Proposes a Mesh adaptive direct search algorithm (MADS) to determine the optimal operating strategy of microgrid with operating cost minimization .In [9] Fuzzy logic based controlled storage is proposed to determine optimal scheduling of microgrid for operating cost reduction.

[10] Presents a modified Differential evolution method to optimize total annual costs of the Microgrid using three sets of distributed energy sources considering load demand scenario. Adaptive modified firefly algorithm has been proposed in [11] to determine the operation management based uncertainty of DGs and Energy storage devices. [12] Proposed Particle Swarm Optimization (PSO) to find the size of BESS while achieving maximum benefit by obtaining minimum operating cost by means of peak levelling and energy saving techniques. Optimal size of BESS is determined in [13] while minimizing the total operating cost of microgrid considering unit commitment problem by using Genetic algorithm. In [14] novel scheduling based algorithm is proposed to optimize the total degradation cost and fuel consumption cost of microgrid in grid connected mode. Firefly Algorithm (FA) proposed in [15] minimizes the total operating cost by considering the capacity based life time degradation model obtaining the size of BESS. In [16] Mixed Integer Linear Programming (MILP) based optimization has been proposed to determine the lithium ion battery degradation assessments in microgird considering SOC range degradation models of BESS. [17] Model Predictive Control (MPC) approach is implemented to integrate the DGs into isolated smart microgrid system to improve the reliability of the system with BESS, neglecting the degradation effect. [18] Presented probabilistic operation and energy management of DERs in a microgrid system under uncertain environment using adaptive gravitational search algorithm considering BESS. Fuzzy based unit commitment model was developed in [19] to reduce carbon emission and to obtain optimal scheduling of DGs for considered Microgrid. From literature it is observed that the operating cost has been minimized without considering life time based degradation effect which results in obtaining infeasible solution and affects the system performance. This paper presents a hybrid renewable microgrid for which an optimal sizing of LI-BESS is carried out to optimize microgrid operating cost and electricity cost considering battery degradation effect.

II. SYSTEM MODEL AND CONFIGURATION

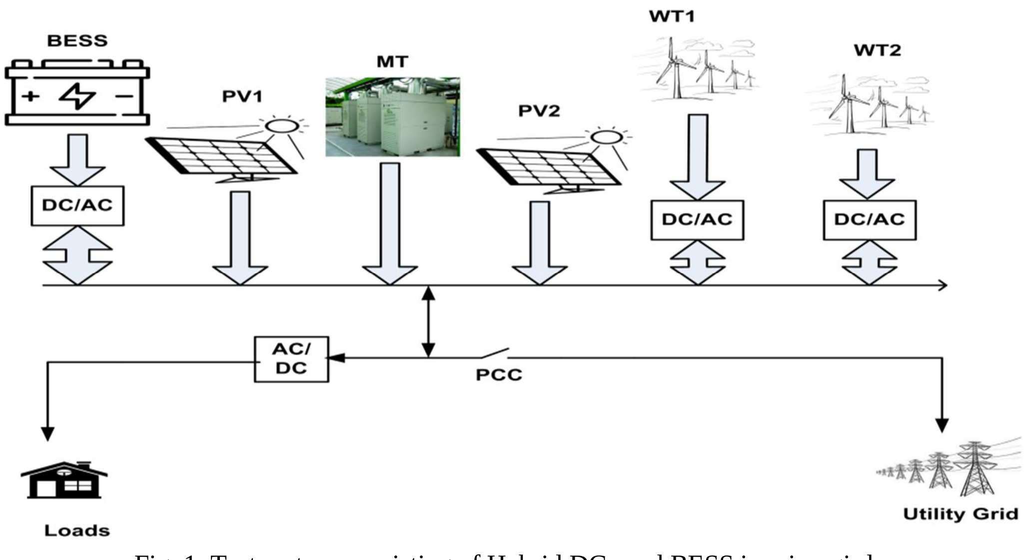

Fig .1. Test system consisting of Hybrid DGs and BESS in microgird.

Fig.1 shows a grid tied residential level energy management system with integration of Hybrid Renewable Energy Systems (HRES) of PVs, WTs, MT and battery energy storage system (BESS). The inverter used in grid connected mode is used for power conversion and to deliver the stored energy from battery to the utility grid. The Battery is discharged depending on the minimum and maximum energy capacity limits of BESS. The operating cost and electricity cost of the considered system is optimized by satisfying the load demand considering battery life time, while accounting for degradation effect in grid connected mode.To ensure the continuity of supply in absence of grid supply due to any outage or etc, microgrid switches in island connected mode which may be either manual islanded mode or automatic islanded mode depending on the type and nature of the load.

A. Modelling of Photovoltaic system

A Photovoltaic system or solar photovoltaic power is designed to supply required electrical power by converting incident solar radiation to electricity. Therefore modeling of PV system output power is a function of solar irradiance which is uncertain. As irradiance is uncertain in nature, the solar output power is also stochastic in nature. The total power generated by PV panels at a time't' is given by equation (1).The solar PV output powers are generated randomly by considering the following equation for different operating points.

$$P_{PV}=P_{STC}.\ (G_C/G_{STC})\ [1 + k\ (T_C - T_{STC})] \qquad (1)$$

Where, G_C is solar irradiance operating point in(kW/m^2), G_{STC} is solar irradiance at STC, P_{STC} is rated power output by PV module at STC, T_C is cell temperature, T_{STC} is the temperature at STC and k is the power temperature coefficient.

B. Modelling of Wind power system

Wind power describes the process of generating the electricity by converting kinetic energy to mechanical power and there by converting to electric power through a generator. As the wind power output is directly proportional to the cube of the wind speed, increased amount of energy can be produced with small changes in wind speed. By considering the uncertainty, output of wind power is expressed in terms of wind speed using wind speed coefficients [21] which is a function of rated, cut in and cutout wind speed, which is expressed by following equation (2).

$$P_{WT} = \left.\begin{array}{ll} a + b*V_w & V_{ci} \le V_w \le V_r \\ 0 & V_w \le V_{ci}\ ,\ V_w \le V_{co} \\ P_r & V_r \le V_w \le V_{co} \end{array}\right\} \qquad (2)$$

Where $a = (P_r\ .\ V_{ci}/V_{ci} - V_r)$ and $b = (P_r/V_r - V_{ci})$

V_{ci} , V_{co} , V_w and V_r are the cut in, cutout, nominal and rated wind speeds respectively. The behavior of wind speed can be simulated by using Weibull distribution function.

C. Modelling of Microturbine

Microturbines are single stage combustion turbines which generate power ranging from few kW to MW. Microturbines are simple form of gas turbines, featuring turbine rotor and compressor which are powered with natural gas or diesel generators and used for small scale power applications [22]. Considering the fuel and installation cost of microturbines, the output powers are generated randomly between minimum to maximum powers and cost function of microturbine can be expressed as in (3), where a and b are cost coefficients taken as 0.0325 and 0.014 and P is output power wrt maximum power generation from the microturbine [23].

$$C\ (P_{MT}) = a + b\ P \qquad (3)$$

D. Modelling of Lithium Ion Battery Energy Storage Systems

BESS plays a vital role in the microgrid system and can help to solve the intermittent nature of DGs. The most important characteristic of BESS is that, it provides emergency backup power to meet the load demand in support of DGs.In this paper LI-BESS is modelled based on battery degradation cost and life time, considering discharge throughputs at each instant of time. The charge and discharge rates at each duration [24] of BESS are expressed as equations (4-5).BESS discharges its power during each hour providing support to DGs to meet the load demand and to get optimal microgrid costs.

$$P_{BES\ charge(t)} = \max\left\{P_{BES\ min},\ (C_{BES,t} - C_{BES\ max})\frac{\eta_{charge}}{\Delta t}\right\} \qquad (4)$$

$$P_{BES\ discharge(t)} = \min\left\{P_{BES\ max},\ (C_{BES,t} - C_{BES\ min})\frac{\eta_{discharge}}{\Delta t}\right\} \qquad (5)$$

$P_{BES\ charge}$ and $P_{BES\ discharge}$ are the charge and discharge powers at each hour instant wrt P_{BES}. $P_{BES\ min}$ and $P_{BES\ max}$ are minimum and maximum BESS capacity limits in terms of power. $C_{BES\ min}$ and $C_{BES\ max}$ are the minimum and maximum stored energy capacity limits of BESS.η_{charge} and $\eta_{discharge}$ are the charge and discharge efficiencies, which plays a significant role in delivering discharging power to the load.

III. PROBLEM FORMULATION OF DEGRADATION BASED MICROGRID OPERATING AND ELECTRICITY COST

In present work Hybrid Renewable Energy Systems (HRES) based microgrid having 2 units of wind, 2 units of PV, 1 unit of MT and BESS are considered to meet the hourly predicted load demand to ensure the reliability in supply and to reduce the intake of power supply from grid there by reducing the electricity cost to customers.The proposed microgrid should satisfy the average load demand of around 1.75 kW by obtaining power from DGs and BESS considering the degradation effect. The objective function is to minimize the operating cost of microgrid with the use of HRES and correspondingly minimizing the electricity cost of customers in grid connected mode. The microgrid operating cost comprised of operation and maintenance cost of DGs and BESS, Total Day Cost (TDC) and degradation cost of the BESS are given by following equations.

$$\mathrm{Min}(O.C)_{MG} = \sum_{t=1}^{T}\{D.G_{\text{releated cost}} + \mathrm{grid}_{\text{releated cost}} + (T.C)_{BESS-DEG}\} \quad (6)$$

$$\mathrm{Min}(O.C)_{MG} = \mathrm{Min}\sum_{t=1}^{T}\left(C_{DG} + MC_{DG} + C_{BESS} + C_{grid} + DEG_{BESS} + TDC_{BESS}\right) \quad (7)$$

C_{DG} and C_{BESS} are the operating costs required to deliver power from respective DGs and BESS. MC_{DG} is the maintenance cost of DGs and TDC_{BESS} is the total day cost of Battery Energy Storage System which includes fixed cost (FC), Maintenance cost (MC) ,Replacement cost (RC) and rate of returns. C_{grid} gives the cost of grid power required to meet demand. DEG_{BESS} refers to total degradation effect cost in rupees which is given by following equation. The degradation effect calculations of BESS parameters to determine degradation cost and life time [25] which is to be incorporated in microgrid operating cost problem formulation are given by the following equations (8-10)

$$DEG_{BESS} = [W * C_{BESS-Max}] \quad (8)$$

Here 'W' gives the degradation cost of BESS in Rs /kWhr which is based on average kWhr throughput and to be obtained from simulations and initial cost of BESS which is given by

$$\text{Battery DEG} - \text{Cost}(W) = \left\{\frac{\text{intial investment cost of battery(Rs)}}{\text{Average kWhr throughput of battery}}\right\} \quad (9)$$

The degradation based life time of BESS which is to be incorporated in Total Day Cost is given by equation 11. The Life Time (LT) here is obtained based on actual kWhr throughput to be obtained from simulations and average lifetime kWhr which is specified by manufacture and is given by following equation.

$$\text{Battery}_{\text{Life Time}}(\text{Years}) = \left\{\frac{\text{Total actual MWh throughput for year}}{\text{Total average life time MWh}}\right\} \quad (10)$$

The total day cost (TDC) and total cost of BESS within Life time(LT) is given by following

$$(TDC)_{BESS} = \frac{C_{BES,Max}}{365}\left\{\frac{IR(1+IR)^{LT}}{(1+IR)^{LT}-1} * FC + MC + \left(C_{BES,Max} * \frac{RC}{(1+IR)^{LT}}\right)\right\} \quad (11)$$

$$(T.C)_{BESS-DEG} = (W * C_{BES-Max}) * (TDC)_{BESS} \quad (12)$$

Determination of average kWh throughput and actual MWh throughputs are the 2 mathematical challenges that is to be incorporated in total day cost (TDC) to obtain the optimal results. Simulations of hourly battery discharges rates and simulation of actual discharge rates with obtained simulated rates need to be calculated to determine the degradation effect.

The total cost of electricity (COE) in Rs/kWhr which is to be minimized satisfying the load demand **is** given by equation 15. To obtain the electricity cost, the obtained COE is to be multiplied with total load demand at that instant of time

$$\textbf{Cost of Electricty (COE)} = \frac{\sum_{t=1}^{T}(C_{PV}+ C_{BESS}+ C_{MT}+DEG_{BESS})}{\sum_{t=1}^{T} P_L} \tag{13}$$

A. Constraints

The microgrid system with HRES and BESS is affected by DGs constraints within their maximum to minimum values of inequality constraints which should be satisfied to obtain optimal operating and electricity costs and BESS constraints given below.

$$P_{BESS\text{-}Min} \leq P_{BESS} \leq P_{BESS\text{-}Max} \tag{14}$$

$$SoC_{Min} \leq SoC_{BESS} \leq SoC_{Max} \tag{15}$$

The LI-BESS size should be optimized within minimum and maximum power capacities of 50 to 500kW with storage capacity of 500kWh. SoC estimation is key component for a battery management system which is based on energy storage capability. State of Charge (SoC) of LI-BESS should be in between 0 and 1 for each hourly discharge duration which indicates fully discharged and charged respectively. The reason to maintain SoC of LI-BESS in between 0 to 1 is because of its high energy density, constant power discharge capability and long life. The typical SoC of LI-BESS is around 80 - 90% [26-27]. Size of BESS in terms of average kWhr throughput and actual kWhr throughput has to be determined so that minimum microgrid operating and electricity cost is obtained.

IV. IMPLEMENTATION STRATEGY WITH HEURISTIC AND LP-IP OPTIMIZATION ALGORITHMS

The objective function for operating cost and electricity bill minimization considering battery degradation cost and life time is solved by using heuristics optimization and solver based LP-IP approach. Under heuristic optimization techniques, Particle Swarm Optimization (PSO), Accelerated Particle Swarm Optimization (APSO) and JAYA algorithms are used to solve the objective. Linear Programming and interior point (LP-IP) solver based approach is used to solve the problem and compared with heuristic techniques to show the effectiveness of LP-IP solver. Results of operating cost and electricity bill minimizations, degradation costs and life time, average kWh and actual kWh throughputs of microgrid for 24hrs have been presented in a comparative analysis.

A. Implementation with PSO, APSO and JAYA

Particle swarm optimization is a population based Meta heuristic algorithm proposed by Kennedy and Eberhart in 1995 by simulating the social behavior of birds [28]. The PSO algorithm starts with the initialization of random particle positions. The accelerated Particle Swarm Optimization (APSO) is the improved version of standard PSO which used only global best (G_{best}) to accelerate the convergence of algorithm The standard PSO uses particle best to increase the diversity in the solutions quality which causes low quality in solutions. Jaya algorithm is a population based algorithm developed by Rao [30] to solve various types of unconstrained and constrained optimization problems. Unlike other optimization techniques, JAYA doesn't have algorithm specific parameters. The only two controlling parameters used in JAYA are population size and total number of iterations. The position and velocity update equations of PSO and APSO are as expressed in (16-19).The main disadvantage of PSO is acceleration and premature convergence of algorithm, which can be overcome by APSO.

$$\mathbf{V_{i+1} = w * V_i + C_1 * R_1 * (P_{best} - X_i) + C_2 * R_2 * (G_{best} - X_i)} \tag{16}$$

$$\mathbf{X_{i+1} = X_i + V_{i+1}} \tag{17}$$

$$\mathbf{V_{i+1} = V_i + (\alpha * R_1) + R_2 * (G_{best} - X_i)} \tag{18}$$

$$\boldsymbol{\alpha = \alpha_0 \gamma^t} \tag{19}$$

Where α_0 is the initial randomness value which varies between (0.5, 1). In this study, value of α_0 is taken as 0.5. R_1 and R_2 are the random number initialization in between 0 and 1, C_1 and C_2 are learning factors which relates the importance to personal best and global best particles taken as 2 and 'W' is the inertia weight constant taken between 0.1 -0.9.

JAYA algorithm achieves successes by providing best optimal solutions by moving away from the worst solution. The position update equation of JAYA algorithm is given by equation (20) considering the worst value of function to improve the quality of solution.

$$\mathbf{X}'_{\mathbf{i,j}} = \mathbf{X}_{\mathbf{i,j}} + \mathbf{R_1}\left(\mathbf{G}_{\mathbf{best,j}} - |\mathbf{X}_{\mathbf{i,j}}|\right) - \mathbf{R_2}\left(\mathbf{G}_{\mathbf{worst,j}} - |\mathbf{X}_{\mathbf{i,j}}|\right) \quad (20)$$

B. Linear programming based interior point (LP-IP) solver

LP-IP solver is used to solve both linear and nonlinear optimization problems considering inequality and equality constraints as variables. LP-IP solver finds minimum of a function specified by following expression.

$$\min_x f(x) = \left\{ \begin{array}{c} A.x \leq b \\ A_{eq}.x = b_{eq} \\ lb \leq x \leq ub \end{array} \right\} \quad (21)$$

Where f(x), b, b_{eq}, lb, ub are vectors and A and A_{eq} are matrices. A and b corresponds to inequality constraints , A_{eq} and b_{eq} correspond to equality constraints and the lower bounds(lb) and upper bounds(ub) correspond to limits of the function which the objective is to be optimized. As 'linprog' function uses interior point algorithm the objective function uses the maximum of 200 iterations. 'X' indicates the optimized value of the function and f_{val} indicates the corresponding values of objective function, where the optimal result has been obtained. Here the maximum value of tolerance is 1e-6 which is fixed for LP-IP solver [31].

V. RESULTS AND DISCUSSIONS

The microgrid operating and electricity costs considering degradation effect with simulation of various BESS degradation parameters has been studied for 24hrs and solved by using heuristic and solver based techniques. Hourly powers generations from wind, PV and microturbine are considered having maximum generation limits for a time horizon of 24hrs. The above objective is achieved by simulating the BESS degradation parameters such as average and actual kWhr throughputs, degradation cost and life time. The throughputs of BESS obtained for each hour helps in determining the BESS degradation costs and life time to DGs output. The BESS degradation simulation parameter has been considered to optimize overall operating and electricity cost and correspondingly average costs are determined. The maximum generation limits is to be satisfied to meet the load demand is given by the following table.

Table.1. Maximum generation limits on DGs and Predicted Load.

Time(H)	PWT1 (kW)	PWT2 (kW)	PMT (kW)	PV1 (kW)	PV2 (kW)	Load (kW)
1.	660	688	429	0	0	1471
2.	699	707	442	0	0	1325
3.	700	698	367	0	0	1263
4.	666	576	450	0	0	1229
5.	669	675	450	0	0	1321
6.	719	674	351	0	15	1509
7.	711	693	532	10	71	1663
8.	712	732	497	67	90	1657
9.	716	746	504	98	116	1643
10.	706	686	507	122	140	1643
11.	678	661	366	139	155	1652
12.	697	638	372	145	163	1666
13.	700	561	350	145	163	1600
14.	693	650	400	133	155	1642

15.	700	652	600	120	133	1640
16.	697	657	138	94	107	1676
17.	700	660	381	61	86	1920
18.	699	659	617	17	46	2000
19.	644	668	652	0	1	2210
20.	674	664	706	0	0	2220
21.	677	661	744	0	0	2150
22.	688	642	696	0	0	1903
23.	694	674	711	0	0	1666
24.	672	649	711	0	0	1665

Table.1. describes the hourly maximum power generation limit of each DG with predicted load demand. The microgrid operating and electricity cost results are obtained satisfying the optimal power allocation of DGs without exceeding its maximum generation limit. Therefore proposed microgrid system should optimize the operating and electricity cost satisfying the hourly load demand of by obtaining power from DGs and BESS considering the degradation effect. The following sets of optimal results are obtained for heuristic and LP-IP solver based methods for different cost related objectives, throughputs and life time of BESS.

Table.2.Life Time comparisons with average and actual throughputs from BESS

Algorithm	Average throughput(kWh)	Actual throughput(MWh) for year	Obtained Life Time(LT)years
PSO	390	3.452	3.16
APSO	396	3.582	3.25
JAYA	405	3.665	3.30
LP-IP Solver	415	3.804	3.51

Table.2 describes the life time in comparison with the average and actual throughputs from BESS. It is observed that, the life time of BESS gets improved in proportion with throughput based discharge from BESS. More the amount of throughputs from BESS greater will be the life time. From the above, solver based method give better results in terms of life time and throughputs.

Table.3. Average BESS degradation cost comparison with microgrid operating cost

Algorithm	Unit Degradation Cost of BESS (Rs/kWhr)	Operating Cost(Rs) with BESS
PSO	105.89	6520
APSO	102.50	6434
JAYA	95.20	6300
LP-IP Solver	90.12	6201

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Table.3 describes the comparative performance analysis of the BESS and micorgrid in terms of degradation cost and operating cost. Degradation cost of BESS is determined considering investment cost and average kWhr throughput and correspondingly operating cost of microgrid has been determined from obtained degradation cost. From the above, it is evident that solver based method gives better performance in terms of system related costs.

Table.4. Average microgrid operating cost comparison with and without BESS degradation effect

Algorithm	Operating cost with BESS without degradation effect (Rs)	Operating cost with BESS considering degradation effect(Rs)
PSO	6435	6520
APSO	6401	6434
JAYA	6320	6300
LP-IP Solver	6145	6201

The above table 4 gives the results of microgrid operating cost considering BESS with and without degradation effect. Equation (9) concludes that the degradation cost effect acts a burden on the operating cost problem formulation. Therefore, from the above results it can be concluded that the operating cost increases by considering degradation effect but there is a gradual improvement in microgrid cost reduction with LP-IP solver when compared to heuristics.

The degradation effect acts as burden on operating cost due to which the cost increases, because it is an additional cost on the system which is added to operating cost. Future, increase in operating cost can be avoided by considering degradation effect which benefits microgrid operator by choosing proper size of battery based on load demand. For electricity cost, degradation effect helps in reducing the electricity bill because the throughput of BESS increases due to inclusion of degradation cost which is more advantageous in minimizing the electricity cost with respect to load demand.

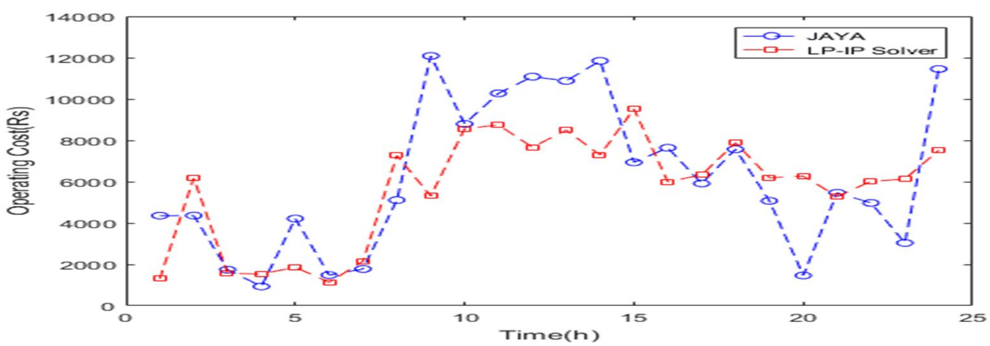

Fig.2.Microgrid operating cost variation with Jaya algorithm and LP-IP solver

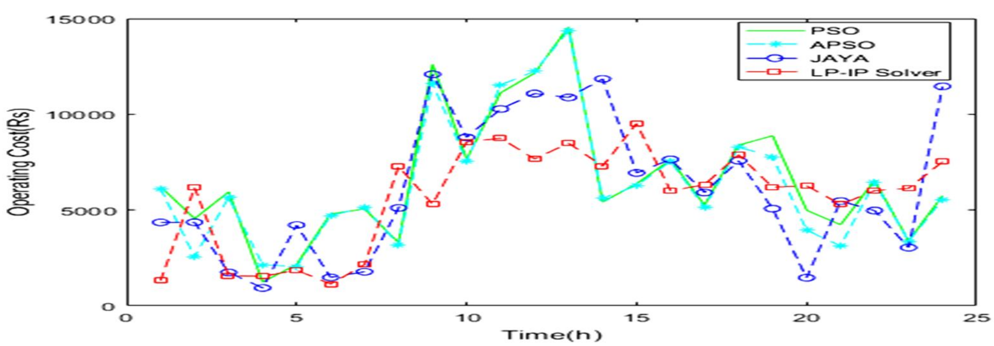

Fig.3. Microgrid operating cost comparison with heuristics and LP-IP solver methods

Fig.2. shows the comparison between JAYA and LP-IP solver method and it is clear that the proposed LP-IP solver gives optimal results for operating cost minimization and delivers best possible solution for scheduling based problems. Fig.3.gives the comparative performance analysis of implemented algorithms for operating cost minimization. It can be concluded that, among performed heuristic based methods, JAYA optimization algorithm performs better among heuristics in most of the cases. It is observed that LP-IP solver effectively minimizes the objective considering the degradation effect while satisfying the load demand for 24hrs among the performed algorithms.

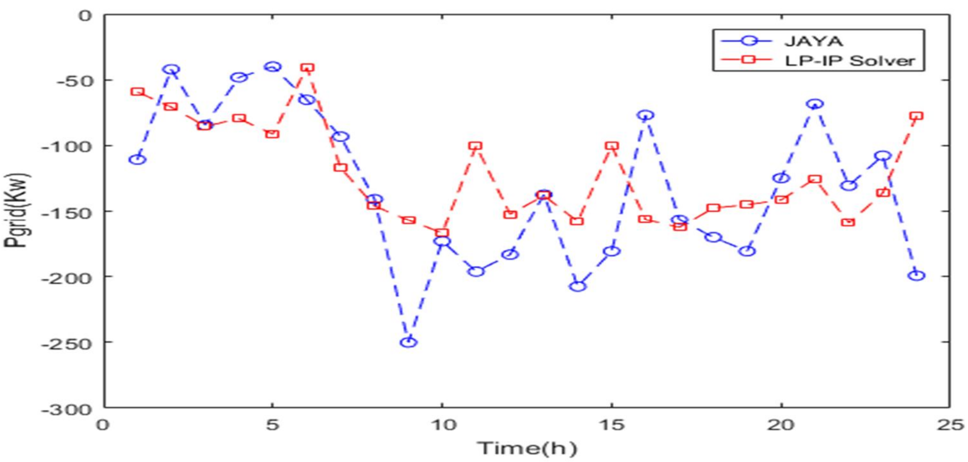

Fig.4. Error plot variation with JAYA and LP-IP solver methods for 24hrs

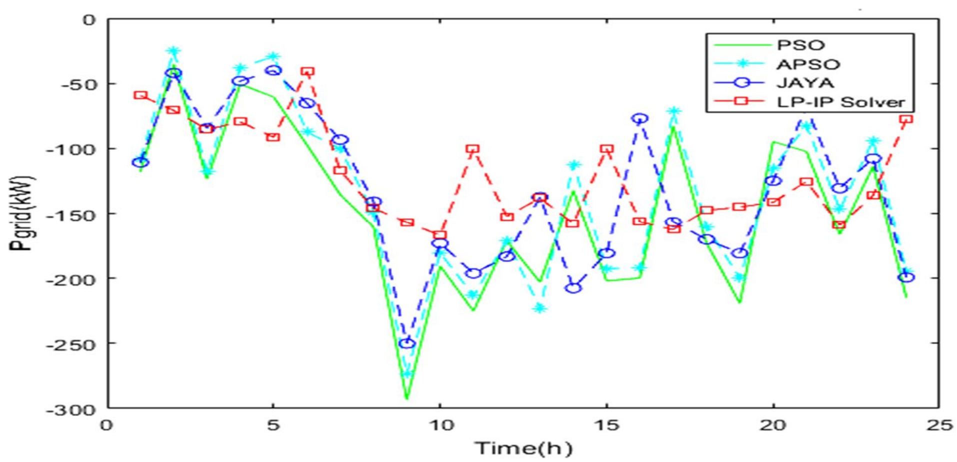

Fig.5. Error plot with comparison heuristics and solver methods for 24hrs

Figures (4-5) show the simulation results of power drawn from the grid (error) for 24hrs using heuristics and solver based methods. From the above results of grid power generations, it can be concluded that solver based method gives optimal error compared to heuristic approaches because maximum amount of throughputs from BESS has been achieved considering degradation effect.

LP-IP method can handle the objective functions that are discontinuous by approximating the constraints of objective as a set of boundaries by modifying them without reaching global minima.

Therefore LP-IP solver algorithm is more accurate in solving the constrained minimization of the function within the bounds and gives optimal solution which is global minima.

Table.5. Simulation parameters and ratings of DGs

Simulation Parameters	Values
Population size	40
Prediction horizon	24 hrs
Maximum number of iterations	200
BESS Power capacities	50 to 500 kW
Wind Turbine ratings	0 to 700 kW
Microturbine ratings	0 to 700 kW
Solar PV ratings	0 to 150 kW
Grid power ratings	0 to 300 kW

Table.5 gives description of simulation parameters for Hybrid DGs and LI- BESS. The optimal operating and electricity cost is obtained while maintaining maximum and minimum power generation limits of DGs and BESS. Whereas for hourly scheduling of DGs and BESS throughputs, obtained results should not exceed the maximum ratings.

Table.6. Simulation parameters for BESS with degradation effect

BESS parameters with Degradation effect	Values
Battery Capacity	500kWh
Battery Power Ratings	50-500 kW
Battery investment cost	43,000 Rs
Maintenance Cost	400 Rs/kWh
Replacement Cost	60 Rs/kWh
Total average life time specified for one year	1.2 MWh
Interest rate	0.05

The above Table6 gives the simulation parameters of BESS considering degradation effect. Considering above BESS parameters, the degradation cost values and life times are determined. Degradation cost and life time of BESS can be obtained by knowing the battery investment cost and total average kWh throughput. By using the degradation cost parameters, the operating cost and electricity cost is to be optimized.

VI. CONCLUSIONS AND FUTURE SCOPE

In this paper operating cost of microgrid has been minimized considering battery degradation effect based life time and correspondingly determined electricity cost to customers considering Hybrid Renewable Energy Resources (HRES).The objective is solved by determining the BESS degradation parameters and implementing with heuristic and LP-IP solver based techniques. The results show that, the LP-IP solver based approach gives optimal results for minimized microgrid operating cost considering BESS degradation effect and its simulation parameters, satisfying the load demand for 24hrs. For maximum throughput from BESS, the degradation cost and operating cost obtained is minimum. For battery capacity of 500kWh the optimal size of battery is determined to be in the range of (350-450kWh) for which the operating cost obtained is minimum. This work can be extended by considering the capacity based degradation depending on percentage degradation and SOC range to optimize the operating and electricity cost considering Hybrid Energy Storage Systems (HESS).

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