# Analysis of integration of Distributed Energy Resources (DERs) in Micro Grid under Demand Response Programs

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A thesis submitted in fulfilment of the
Requirement of the degree of Master of Science
(Electrical Engineering)

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BAHRIA UNIVERSITY ISLAMABAD
FEBRUARY 2022

# APPROVAL FOR EXAMINATION

Scholar's Name: **IRAJ ILYAS** Registration No. **01-244201-004** Programme of Study: Master of science in Electrical Engineering Thesis Title: ANALYSIS OF INTEGRATION OF DISTRIBUTED ENERGY RESOURCES (DERS) IN MICROGRID UNDER DEMAND RESPONSE PROGRAM**.** It is to certify that the above scholar's thesis has been completed to my satisfaction and, to my belief, its standard is appropriate for submission for examination. I have also conducted plagiarism test of this thesis using HEC prescribed software and found similarity index __________% that is within the permissible limit set by the HEC for the MS degree thesis. I have also found the thesis in a format recognized by the BU for the MS thesis.

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# DEDICATION

To my father **RAJA ILYAS LATIF**, who has always been a source of encouragement, his strong support and trust gave me the confidence to achieve my goals.

**Engr. Iraj Ilyas**

**Enrolment No. 01-244201-004**

# ACKNOWLEDGEMENT

A thesis report of this breadth and scope could not possibly be assembled by a group of undergraduate students working alone, and so several words of thanks are in order. First, we would like to thank God Almighty for bestowing us energy and will that enabled us to compile and produce this report. Next, we would like to thank Associate Professor **Dr. Asad Waqar** Bahria University Islamabad**.**

We also thank him as he is our project supervisor who helped us in every difficulty which we faced while completing this project. He always encouraged us in problems solving during the project. It is important to thank the ones people who've supplied mainly beneficial assistance, technical or otherwise, throughout the thesis. The manager will glaringly be thrilled to be stated as he or she can be able to have invested pretty a whole lot of time overseeing your progress.

# ABSTRACT

The microgrid is a new genre of integrating the distributed energy resources (DER) within the grid. However, literature studies with the consideration of RERs uncertainty and DRPs of grid-connected EVs integrated residential PV-WT-FC-DE based community rural microgrid (MG) by employing single objective problem using ABC/PSO algorithms is missing. This work modeled a household energy management comprising of microgrid (MG) system and DRPs. Residential loads with price-based tariffs are introduced for reduction in peak load demands and energy costs. For modeling uncertainties in RERs, their stochastic nature is modeled with probabilistic method. In this paper, a joint optimization approach is proposed for the optimal planning and operation of grid-connected residential rural MG integrated to renewable energy and electric vehicles (EVs) in view of DRPs. The investigation focuses on energy saving of residential homes under different DRPs and RERs integration. The EVs are integrated to MG by including photovoltaic (PV), wind turbines (WT), fuel cell (FC) and diesel engine (DE). A multi objective optimization problem has been formulated to minimize the Operating Cost, Pollutant Treatment Cost and Carbon Emissions Cost defined as C1, C2, and C3 respectively. The load demand has been rescheduled in view of three DRPs i.e., critical peak pricing (CPP), real time electricity pricing (RTEP), time of use (TOU). Further, the EV load has also been analyzed in the form of autonomous and coordinated charging strategies. The proposed multi objective problem is transformed into a single objective problem using artificial bee colony (ABC) algorithm and the results are compared with particle swarm optimization (PSO) algorithm. The simulation analysis was accomplished employing ABC and PSO in MATLAB. The mathematical model of MG was implemented, and the effects of DRPs based MG were investigated under different number of EVs and load data in terms of reducing different costs. To analyze the impact of DRPs, the residential rural MG is implemented for 50 homes with a peak load of 5 kW each and EV load with 80 EVs and 700 EVs respectively. The simulation results with the total 32 test cases are formulated, while analyzing the tradeoff between ABC and PSO algorithms. The simulation analysis shows that multiple DRPs, EVs, and RERs offered substantial trade-off.

**KEYWORDS:** Demand response programs (DRPs), distributed generations (DG), electric vehicles (EVs), joint sequential optimization, multi-objective optimization, residential microgrids

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| ABC | Artificial bee colony |
| BBSA | Binary BSA |
| BSA | Backtracking search algorithm |
| BSS | Battery storage system |
| CCP | Chance constraints programming |
| CPP | Critical peak pricing |
| DE | Diesel engine |
| DERs | Distributed energy resources |
| DG | Diesel generator |
| DGRs | Distributed energy generations |
| DOD | Depth of discharge |
| DRPs | Demand response programs |
| DSM | Demand side management |
| EMA | Exchange market algorithm |
| EMS | Energy management system |
| ESRMC | Energy and spinning reserve market clearing |
| ESS | Energy storage system |
| EVs | Electric vehicles |
| FC | Fuel cell |

| | |
|---|---|
| GA | Genetic algorithm |
| GAMS | General algebraic modeling system |
| GHG | Greenhouse gas |
| GSA | Gravitational search algorithm |
| HES | Hybrid energy system |
| HOMER | Hybrid optimization of multiple energy resources |
| LCOE | Levelized cost of energy |
| LPSP | Loss of power supply probability |
| LSA | Lightning search algorithm |
| MBAT | Modified bat Algorithm |
| MILP | Mixed integer linear programming |
| MIP | Mixed-integer programming |
| MOPSO | Multi-objective PSO |
| MPGSA | Multi-period GSA |
| MPSO | Modified PSO |
| MT | Micro turbine |
| NPC | Net present cost |
| NREL | National renewable energy laboratory |
| OPF | Optimal Power Flow |
| PDFs | Probability density functions |
| PFs | Participation factors |
| PQ | Power quality |
| PSO | Particle swarm optimization |

| | |
|---|---|
| PV | Photovoltaic |
| RERs | Renewable energy resources |
| RO | Robust optimization |
| RTED | Real-time economic dispatch |
| RTEP | Real time electricity pricing |
| SA | Simulated annealing |
| SG | Smart grid |
| SNO | Social network optimization |
| SPEA | Strength Pareto evolutionary algorithm |
| TOU | Time of use |
| TS | Tabu search |
| V2G | Vehicle-to-grid |
| WGA | Wild goat algorithm |
| WT | Wind turbine |

# Chapter 1

# Introduction

# Chapter 1

# Introduction

## 1.1. Demand-side management (DSM):

DSM is characterized as "the arranging, execution, and checking off those utility exercises intended to impact client utilization of power in manners that will deliver craved changes in the utility's heap shape, i.e., fluctuations in the schema and magnitude of a utility's load".

To daunt the energy usage in peak hours or propel the time of usage to off-peak time such as nighttime or weekends is the main pursuit of DSM. DSM doesn't lessen full energy practice yet could be anticipated to reduce the need for benefits in networks and power plants for satisfying peak demands. A model is the utilization of energy-gathering gadgets to store energy during off-top hours and release them during top hours. A more current application for DSM is to help framework administrators in adjusting discontinuous age from wind and sunlight-based units, especially when the circumstance and greatness of energy requests don't correspond with the inexhaustible age.

Energy governance of the smart grid has DSM as a crucial factor. By and large, DSM alludes to dealing with the customer's energy utilization in such a manner to yield wanted changes in load profile and works with the punters by offering them inducements. For this intention, numerous DSM techniques have been proposed e.g., including peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shape.

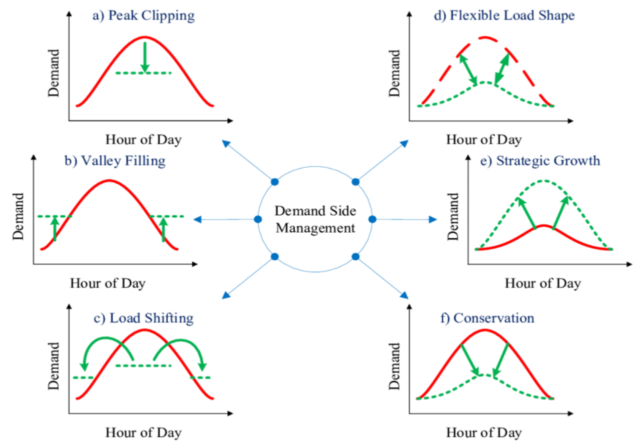



fig 1.0.1demand-side management strategies

As of late, one of the vital DSM exercises is demand response (DR), it is postulated that DR is the split of DSM at a more extensive angle. DR is characterized as the taxes or projects set up to impact the end clients to reshape their energy utilization profile contemplating power cost. DR program is additionally sorted into two kinds, an incentive-based program, and a price-based program. To render the vendee with pecuniary enticements on the base of load diminution, an incentive-based program is used.

Then again, a price-based program stipulates the cost of power during various time stretches. The motivation behind the price-based program is to lessen power use when the power cost is high and subsequently, decrease demand during top periods. Day-ahead pricing, RTEP, time of use (TOU), CPP, and inclined block rate, are Price-based programs.  DR is considered a vital component in smart grid to work on the manageability and dependability of smart grid. Nonetheless, it is analyzed in the writing that analysts considered the DSM and DR to be exchangeable.

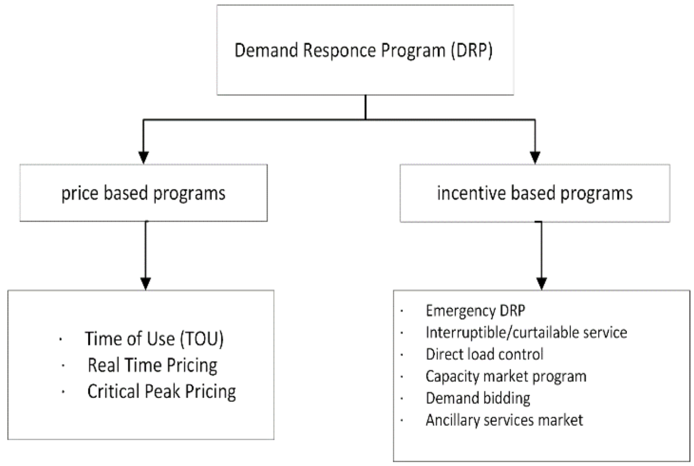



fig 1.2 core element of a demand response program

## 1.2. Distributed Energy Resources (DERs):

Expanded requests on the countries electrical force frameworks and occurrences of power deficiencies, power quality issues, planned power outages, and power value spikes have made numerous utility clients look for different wellsprings of superior grade, dependable power. Distributed Energy Resources (DER), limited scope power age sources found near where power is utilized (e.g., a home or business), give an option to or an upgrade of the conventional electric grid.

Miniature, integrated, energy generation and storage tech that provides electric capacity or energy where coveted, it is called Distributed energy resources. Commonly creating under 10 megawatts (MW) of power. DERs can typically operate in either grid-connected or islanded mode.

Common examples of DER technologies involve wind turbines, photovoltaic (PV), fuel cells, micro turbines, reciprocating engines, combustion turbines, cogeneration, and energy storage systems.

Fig. 1.3 is schematic configuration of the rural community micro grid.

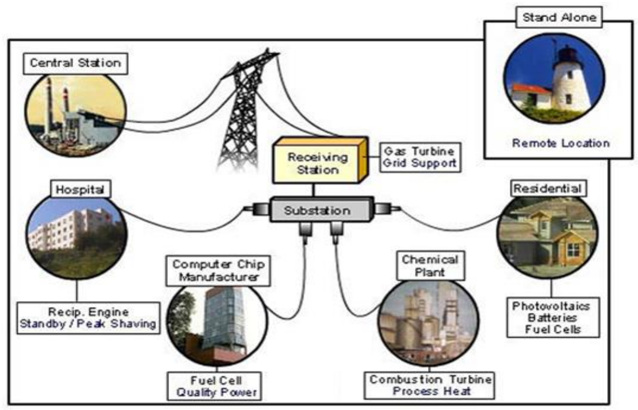



Fig 1.3 Distributed Energy Resources (DERs)

## 1.3 Problem description:

Soon, the global demand for energy is growing rapidly, and much of the demand for responsibility lies in the general production of mineral energy. With this increase in energy demand through conventional energy production, there is an increase in global warming and land pollution. To overcome this, micro grid (MG) with different generations of energy distributed such as solar, wind, fuel cell, MT, etc. is a better choice than conventional fuel production [1],[2]. In MG, bulk of power produced substantially relies on renewable energy resources (RERs), which are usually intermittent in nature. MG central controller (MCC) is executed to well handle the ambiguities of load demand and renewable power production in the MG environment it also regulates and handles all the MG component operations. There are some other advantages of ideal MG operation in the smart grid environment, such as [3]-[5].

- quality improvement
- more adaptable system
- extra environmentally sustainable function
- less electricity expenses
- self-manageable
- protection and energy management

- Reducing polluting secretions power quality improvement and so on.

MGs have the expertise in employing demand response programs (DRPs) for stabilizing the system loads due to insertions of shift able loads [6], [7]. Hence, sizing problems and optimal scheduling are pondered as the vital issues. Additionally, the provision of RERs alongside their operation ambiguity have identified knotty trials for optimal operation [8], [9], which must be deemed at the designing arena so that the overall system can work appropriately.

## 1.4 Thesis objective

When renewable energy sources (RES) are installed in Microgrid (MG) there is an exponential increment in Total Annual Cost (TAC) and Total Annual Emissions (TAE). Total annual expenditure and total annual greenhouse gas emissions are viewed from an economic and environmental point of view. Due to these issues, there are climate crises as well as increased energy cost. So, the objectives of this research is

- Total Annual Cost (TAC)
- Total Annual Emissions (TAE)

## 1.5 Thesis Organization

The organization of this thesis is as follow:

- Chapter 1 reviews Introduction, Overview, Problem description, thesis objective andthesis organization.
- Chapter 2 detailed literature review explained.
- Chapter 3 detailed methodology explained.
- Chapter 4 results and discussions
- Chapter 5 conclusion

# Chapter 2

# Literature Review

# CHAPTER 2

# LITERATURE REVIEW

The demand for energy is rapidly increasing all over the world. Currently the demands are fulfilled by conventional generation using fossil fuels. However, the generation from fossil fuel causes environmental pollution and global warming. To overcome these challenges, the hybrid and distributed generation systems (DGs) are introduced. The micro grid (MG) manages the hybrid generation system, which is less dependent on the fossil fuels. MG is very intelligent, and it handles all environmental issues. It continuously monitors the load demand and handles the DGs according to the load demand. The priority is to fulfill the load demand causing less pollution. The DGs include the generation from solar PV, fuel cells, wind turbines and diesel generators [1],[2].

Apart from conventional generation system, the MG plays an important role in managing different generation systems and balancing the environment of smart grid (SG). There are two modes mainly in which MG works i.e., standalone and grid tied. It is observed that most of the time MG power generation depends on the renewable energy resources. MG monitors the nature of load and their uncertain demand at any time as well as the generation from the renewable resources. These all operations are managed by MG unit. There are a lot of advantages of using optimal MG operations in smart grid environment including higher reliability, low cost of energy, less pollution, balanced load, automatic control operations, high operation flexibility and improved PQ [3]-[5]. Loads are of different natures such as shiftable loads. The shiftable loads require proper demand response program to manage and balance the load [6],[7]. However, the MGs also face some complex problems like availability of renewable energy resources with their operations to fulfill the demands. To achieve the optimize schedule and sizing, problems are also there [8],[9]. One must consider these issues at the designing stage of MG based distribution system. A lot of research work is done on it where different scenarios are discussed based on problems with DRPs.

Literature review has shown some of the problems with DRPs and has done their comparative analysis. The algorithms, their contribution and limitations are discussed one by one in coming paragraphs. In this paper [10], the PSO algorithm is used, and it does optimal allocation of ESS, but it consumes a lot of time during computation and do not converge properly. In paper [11], MOPSO algorithm is used. The operating cost is reduced which maximizes the MGs revenue, but it requires bidirectional operation to enhance the reliability. In paper [12], GA algorithm is used. The GA algorithm gives better MGs optimal schedule. The limitations of GA are that it requires multiple set of parameters. In paper [13], MPGSA algorithm is used. This algorithm is beneficial for standalone MG system as it ensures better optimal operation with low production cost and high efficiency. But it has high degradation with reduced life. In paper [14], MBAT algorithm is used. The computation time is less and it has better optimal scheduling in case of MG connected with grid. But it only investigates single load at a time without emission cost of DE. In paper [15], CCP algorithm is used. Three level system with day ahead scheduling is used and the cost of ESS is also degradable. But this algorithm does not tackle the uncertain load. In paper [16]. MPSO algorithm is used. It also deals with the uncertain load and minimum LCOE with optimal power sharing. It also has limitations as BSS and DE are not included. In paper [17], BBSA algorithm is used, which deals with optimal scheduling. The power generation cost is also reduced with minimum losses and the reliability is also increased. But it also has limitations as BSS charging and discharging scenarios are not considered, which needs proper investigation. In paper [18], RO-GAMS algorithm is used. This algorithm covers the previous gap and supports the standalone MGs with shift able loads. Renewable energy resources uncertainty was also applied with RO. But this algorithm does not support the EVs load, and it considers only one DRP. In paper [19], LSA algorithm is used, which is useful at the time of designing of optimized controller. It handles the uncertainties associated with MGs and it ensures low cost with optimum power delivery. But again, EV loads and DRPs are not considered.

In literature review, many articles have been published in which different heuristic methods are discussed. In paper [20], the technique for searching discrete harmony is discussed to manage a hybrid model of PV-WT-BSS-DG. In paper [21], the optimal configuration challenge is handled by hybrid SA-TS algorithm. In paper [22], the two layers' algorithm is proposed for optimal allocation of grid tied HES. The first layer algorithm discusses renewable energy resources optimization, and the second layer algorithm deals with the optimal BSS capacity. In paper [23], the SNO algorithm to optimize the rule based standalone HES is considered. In paper [24], the optimization algorithm is introduced which is basically double loop two level algorithm. It allocates the switching capacitors and manages reactive power. In paper [25], the evolutionary technique for multi objective is introduced, which controls the PV-WT-BSS-DG system. In paper [26], the WGA-EMA with additional property of parallel processing quality is proposed. The reconfigurations of MGs and distribution networks is also done. In paper [27], novel algorithm is proposed in which optimal sizing and residential MGs planning is done in order to minimize the energy cost.

Apart from different algorithms, different tools are also used for optimization of micro grids and EMS. For optimal allocation and optimization of size of MG, HOMOR was also utilized [28]. Moreover, GAMS was also implemented with HOMOR to optimize the islanded MG components. HOMER and GAMS software was also used [29]. Some articles from the literature review shows that mathematical methods were also used instead of heuristic algorithms. The novel optimization technique was used to optimize the size of hybrid PV-WT-DG model [30]. To minimize the risk in profit and to optimize the MG planning the method is proposed in paper [31]. The author proposed the new deterministic method in which LCOE and LPSP algorithm is proposed for size optimization of standalone PV model [32]. In paper [33], the author proposed the two-level predictive algorithm. This algorithm is based on EMS with MILP for standalone MG. The first level deals with unit commitment and the second level deals with the regulation of real time operation of MG.

Another important and critical problem is to select the efficient objective function, which should be suitable enough to optimize the sizes and allocation. In paper [21], the objective function is used to optimize the size and it minimizes the cost of energy associated with MG. The objective of the function is based on MG, where LCOE and LPSP is minimized and the

RERs penetration is maximized [27]. In this paper, the author claims that in addition to optimal sizing the investment cost would be minimum and would also be reliable [32]. In paper [34], the author introduced the novel scheme for optimization of size. The author discusses the energy trading of standalone micro grids. In this way the MG owner can maximize the profit and enhance the reliability of the overall system.

The performance of MG is influenced by various factors in terms of the allocation and size optimization such as challenges related to environment, DRPs, ESS etc. In literature some articles discuss the impacts of these factors in detail. In paper [21], the author conducted the sensitive case studies on renewable energy resources intermittency. The optimal sizes of the components of MG were also found by using single objective function. The renewable energy intermittency was also incorporated by finding their Probability density function (PDFs) [35]. In paper [36], the author applies deterministic uncertainty approach rather than finding PDFs. An advanced techno economic technique is introduced with HES for designing of MG system. In this paper, different schemes of load shifting and their impacts on sizing of MG are also discussed in detail [37]. The DRPs are used for the reduction in cost and the size of MG is also improved by this method [30]. In this paper [38], the environmental impacts of optimal size are analyzed. The limitations of this work are that the RERs with their loads and their uncertain behavior are not highlighted. The yearly samples of RERs and loads with 24 hours step time are used for testing. The HOMOR tool is used for investigation of DERs. The author also observes GHG emissions and their environmental impacts in his study [28]. Similarly in paper [30], the author studies the impacts of ESS on sizing of MG. It is concluded that the investment cost is reduced by installing BSS to standalone HES.

In paper [39], the conventional method in which RTED snapshot data was forecasted for 15 minutes was replaced by adding the variation in RERs and loads data each minute. The ‘’best-fit’’ PFs of power unbalancing is managed by DGs. Previously this data was obtained from previous ED, later on only PFs were evaluated at the start. That approach was applicable on both dynamic and sequential variability. There were two test systems used for the verification of this scheme. In paper [40], the author applied their techniques on wind thermal systems. The author proposed two models. In first model thermal alone was considered and in second model thermal DGs were also considered. The scheme proposed for the system is SPEA2 + bi-objective ESRMC. Also, the stochastic nature of wind was handled by Weibull PDF and load was handled by normal PDF. This scheme was applicable on IEEE 30 bus system. In paper [41], the author proposed the stochastic optimization technique. This technique was used to control voltage and VA under variable loads and uncertainty of RERs. This technique was applicable on 24 bus system. In paper [42], the author considered the emergency conditions e.g., increment in load or any interruption that occurs in line. He proposed optimal, dynamic, fast and slow reserve action technique for this. This technique was applicable on the IEEE 30, 57 and 300 bus system. The GA, MATLAB and GAMS software were used for their implementation.

The previous literature review is summarized, and the limitations are mentioned below:

- At a time, only one DRP is entertained. Also, EVs load and operations related to grid-connected are not considered [18].
- There was no investigation made on BSS charging and discharging scenarios [17].
- EV's BSS are not considered [16].
- The cost of DE emission and the load uncertain nature are not considered [15].
- No DE emission cost is investigated with single loads [14].

A grid connected MG is taken into account, which is basically residential PV-WT-FC-DE based. This MG is integrated of EV with the help of multiple DRPs. For its operation and planning, joint optimization technique is proposed. C1 is considered as operation cost, C2 is considered as pollutant treatment cost and C3 is considered as carbon emission cost. All the three costs are reduced with the help of using multi-objective optimization formula. The DRPs such as CPP, RTEP and TOU are used to reschedule load demand. Moreover, autonomous and coordinated charging strategies are used to analyze EV loads. An ABS algorithm is used to transform multi-objective optimization problem to single objective problem and then their results are analyzed and compared with PSO algorithms. A residential based MG is used for 50 homes, having peak load of 5 kW each and EV loads of 80 and 700 EVs respectively. The impact of DRPs is analyzed on basis of the above setup.

In a nutshell the major contribution of this proposed work is summarized as

- Two heuristic algorithms are compared under three DRPs.
- Instead of using islanded MG cases (mostly used in literature studies), this study considered analysis based on grid-connected MG.
- In literature review, single objective problems using ABC/PSO algorithms are missing but our study will consider ABC/PSO algorithms.
- There is a tradeoff scenario between two heuristic algorithms. Our study will consider this case with load rescheduling with major part of three DRPs.
- EVs loads are investigated with an autonomous and coordinated charging scenarios.
- Different tariffs are defined, and load demand is rescheduled respectively, and economic dispatch is done using DSM techniques.
- The stochastic nature of uncertainties in RERs is modeled with probabilistic method.

# Chapter 3

# Methodology

# CHAPTER 3

# Methodology

In the proposed model, the throng of smart residential households and diverse DERs, such as PV units, WTs, MTs, DEs, and BESS formulates the residential MG. On the generation side, All DERs and the main grid are essential entertainers. All the sections in the MG optimally coordinate with the MCC by using an advanced communication and control network. A total of 50 smart residential consumers are considered in this model as the MG load demand. Smart meters are linked to different consumer electronics, such as NSAs, TSAs, and PSAs. Residential scheduler (RS) units are used to manage and control the electric flow and usage of all smart homes, so they are connected to all smart meters. The RS unit gathers all home appliances' aggregated energy consumption details and transfers the same to MCC for MG planning and operation optimization process. Thereafter, the RS unit executes the scheduling operations of all home appliances according to the MCC's optimization responses.

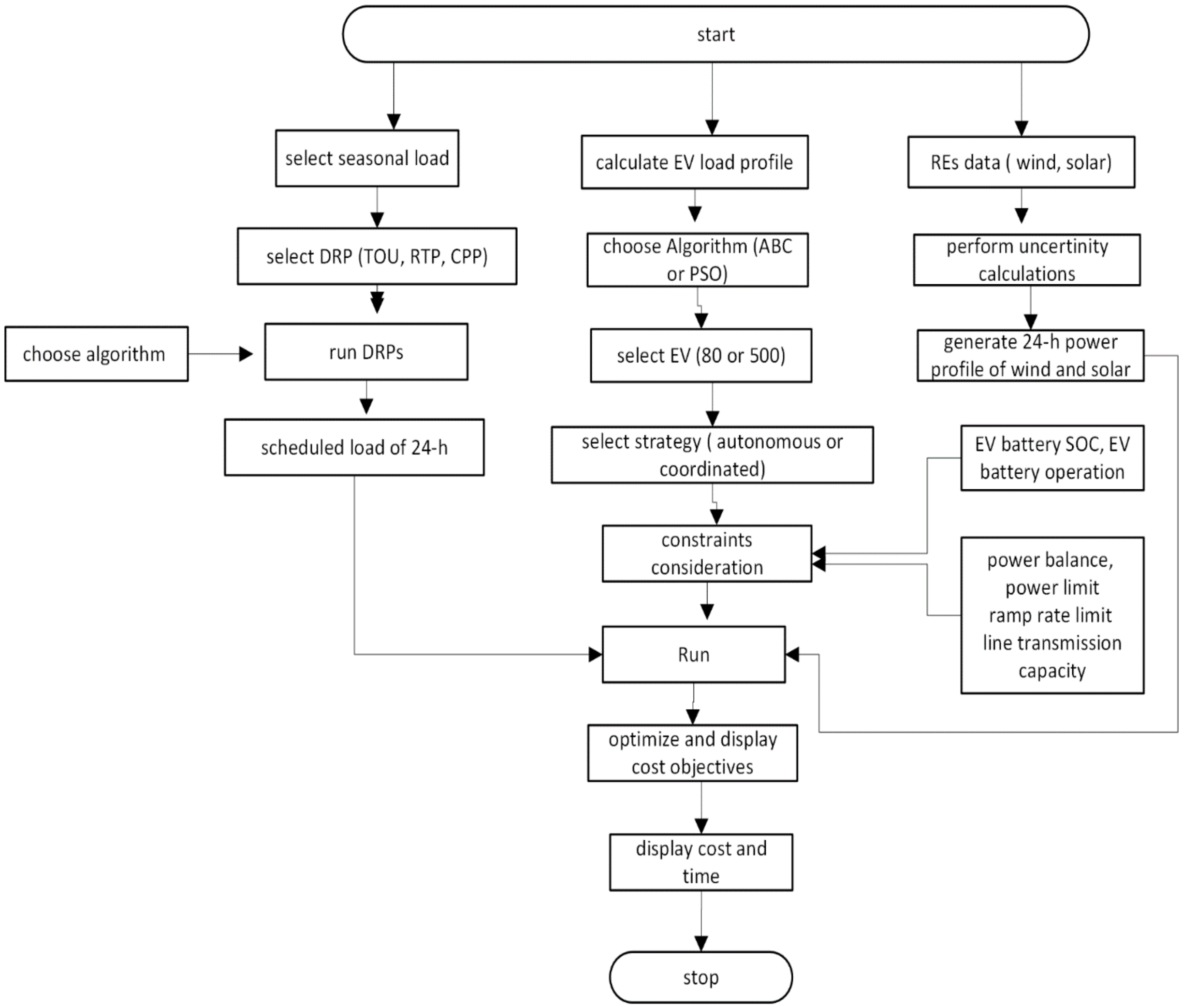



*fig 3.1 Flowchart of proposed optimization methodology to find feasible scheduling for DSM and optimal DGs sizing*

## 3.1 Load model of EV

### 3.1.1 Autonomous Mode

In this mode charging of EV is commenced by its holder under the policies levied by government whilst the EV scheduling activity is not in action. We can express the unilateral power flow with the charging period as:

$$T_C = \frac{SW_{1000}}{100Pc_{\eta C\_EV}} \tag{3.1}$$

where W100 indicates the power utilization (kWh/100km)

PC is charging power (kW),

$\eta C\_EV$ is charging efficiency

To find the sum of the charging load $P_{evload}$ (t) add up the values of each duration interval. Since charging periods of EVs are not reliant on either consequently the following equation can be employed to get the daily load curve:

$$P_{EVload}(t) = \sum_{i=1}^{N} P_i(t) \tag{3.2}$$

where N is the sum of vehicles

$P_i(t)$ is the charging power

$i$ is duration interval t (kW).

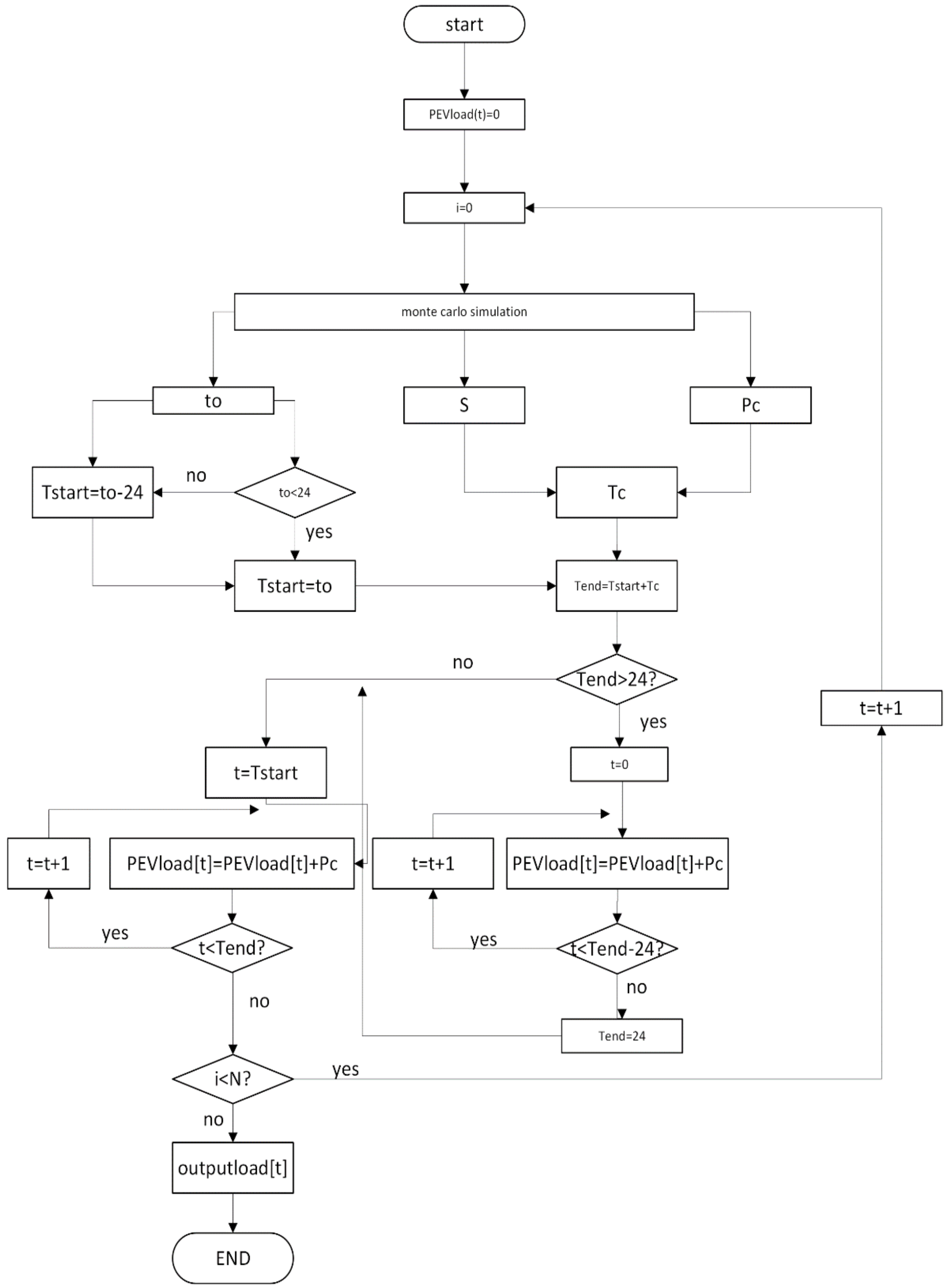



*fig 3.2 flow diagram for computational load autonomous mode*

### 3.1.2 Coordinated Mode

The coordinated mode (V2G) is meant to control EVs properly and centrally by keeping in view the electricity pricing policy and the behavior of the owners. Grid-connected EVs which are scheduled are analyzed. The assumption is made that these EVs can be completely scheduled. EVs will be charged during off-peak load durations, while EVs will be discharged during peak load hours. The maximum discharging duration can be calculated from the battery SOC, daily mileage, and discharging power as follows:

$$T_{\max\_disC} = \frac{(SOC_{max} - SOC_{min})C_{EV}}{P_{disC}} - \frac{SW_{100}}{100P_{disC}} \tag{3.3}$$

The actual discharging time $T_{disC}$ when EVs are discharging can be calculated as follows

$$T_{disC} = T_{end\_disC} - T_{start\_disC} \tag{3.4}$$

The EV charging demand is the sum of total utilization in the everyday period, which includes daily transport utilization and discharge capacity as follows:

$$W_{EV} = P_{disC}T_{\max\_disC} - P_{disC}T_{disC} \tag{3.5}$$

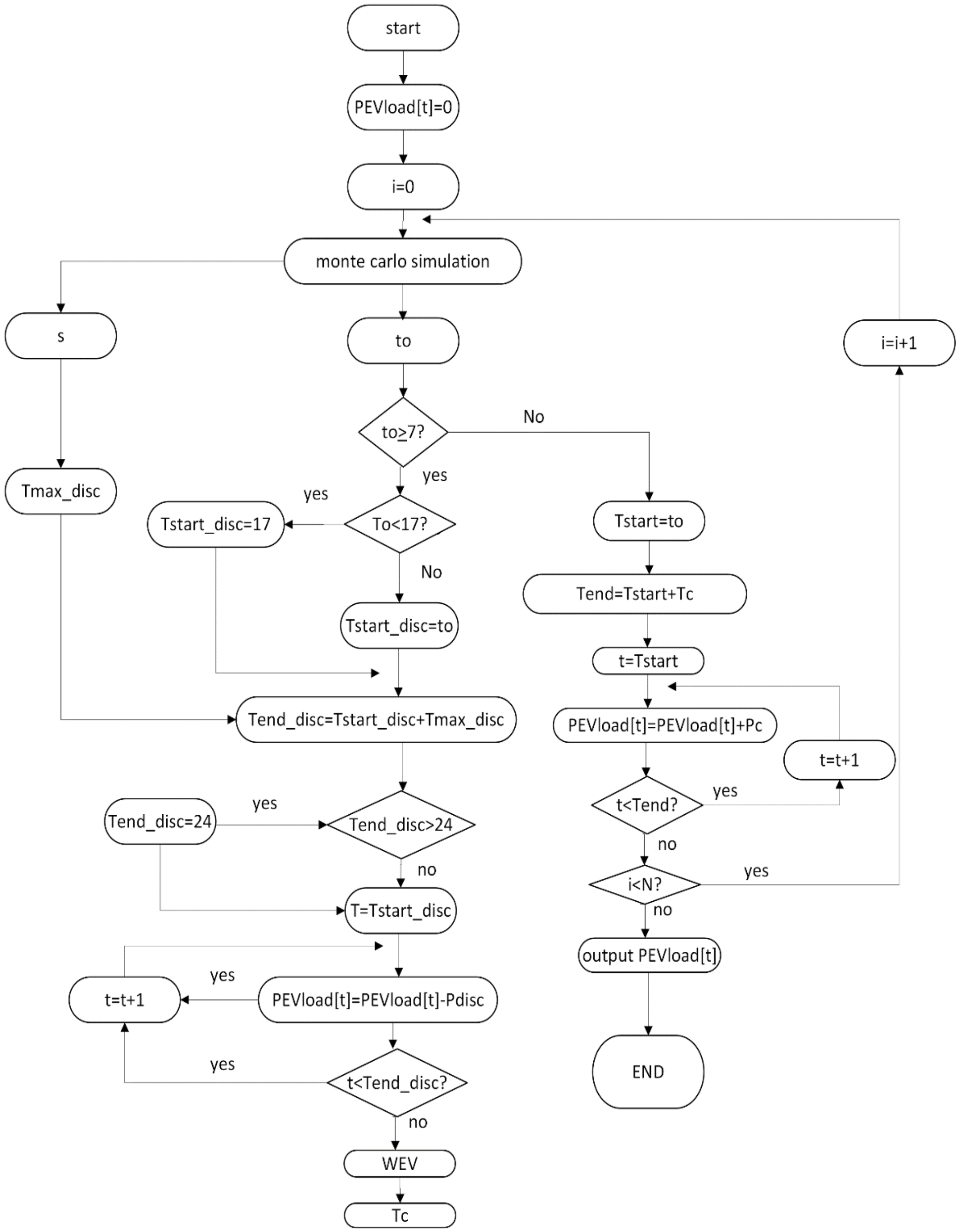



*fig 3.3 flow diagram for computational load coordinated mode*

## 3.2 ECONOMIC DISPATCH STRATEGIES

Since Micro grid (MG) operates in two different modes i.e., Grid-connected, and islanded. For two different operating modes OF MG following scheduling strategies are used.

### 3.2.1 Grid-connected

In grid-connected mode following two methods of the scheduling strategies for economic MG operation are embraced.

- *SCHEDULING SCHEME 1*

During this scheme, the autonomous mode is selected, and Electric vehicles are charged. For the conventional load and EV charging the load, which includes conventional and EV charging, is supplied by DGs and the PG. Power flow is in both directions

- *SCHEDULING SCHEME 2*

In this scheme the EVs are charged as well as discharged since this scheme operates in coordinated mode. EVs are charged during off-peak, and energy is stored in batteries so that it can be discharged in peak hours. Renewables and PG are used as supply for conventional load and charging of EVs. Furthermore, EVs are used for transportation. It is a Bidirectional power flow.

### 3.2.2 Islanded

In islanded mode following two methods of the scheduling strategies for economic MG operation are embraced.

- *SCHEDULING SCHEME 3*

This scheme operates in autonomous mode. DGs are employed as supply for EV charging and conventional load. Frequent charging and discharging can affect battery life so to avoid this BSS (Battery Storage System) is used in specified time, i.e., peak hours from 17:00 to 23:00 and off hours are 24:00 to 06:04. One segment will be terminated if DGs output is not adequate to meet up the requisite.

- *SCHEDULING SCHEME 4*

This scheme works in coordinated mode i.e., charging and discharging of EVs is carried out in coordinated mode. Here the peak and off-peak load hours will be changed. Charging time of BSS is 17:00-24:00 whereas discharging will be carried out at 0:00-6:04. Distributed generators (DGS) and electric vehicles (EVs) are used as supply to the system load including conventional and EV charging. One segment will be terminated if DGs output is not adequate to meet up the requisite

## 3.3 Proposed algorithm

The proposed models are confirmed and investigated with various contextual analyses. Here we applied two algorithms Particle Swarm Optimization (PSO) and Artificial Bee Colony (ABC) under different operation and control methodologies.

### 3.2.1 PSO Algorithm

Kennedy and Eberhart in 1995 proposed a search and intelligence-based optimization algorithm called Particle Swarm Optimization (PSO). Planting a swarming group of random numbers is the basic notion of this algorithm.

To characterize the position of every swarm given equation is used.

$$X_i = (x_{i1}, x_{i2}, \dots., x_{id})^T$$

$$V = (v_{i1}, v_{i2}, \dots., v_{id})^T$$

Where V is the velocity of each swarm and

i = 1, 2, . . ., n, n is the population size.

The expression given below is used by every swarm to adjust its position and velocity continuously, till end measures:

$$\begin{cases} x_{i,d}^{k+1} = x_{i,d}^{k} + v_{i,d}^{k} \\ v_{i,d}^{k} = \omega v_{i,d}^{k} + c_1.rand_1^k \\ (pbest_{i,d}^k - x_{i,d}^k) + c_2.rand_2^k.(gbest_{i,d}^k - x_{i,d}^k) \end{cases} \quad (3.6)$$

Where.

$x_{i,d}^{k+1}$ is the position of a swarm i in $k^{th}$ iteration. [1]

$v_{i,d}^{k}$ is the velocity of a swarm in $k^{th}$ iteration.

$\omega$ is the inertia weight factor.

$c_1, c_2$ are acceleration coefficients.

$pbest_{i,d}^{k}$ is personal best

$gbest_{i,d}^{k}$ is global best

$rand_1^k$ and $rand_2^k$ are random numbers

Following are the steps of the PSO algorithm.

- Initialize swarm with its velocity and location, constants, and highest iterations.
- Settle the fitness value as a target.
- Compute the fitness for every swarm for personal best, in the meantime comparing with other swarms for global best.
- Revise swarm velocity and position.
- Revamp both personal best and global best results appropriately.
- Revive steps 4 and 5 in anticipation of achieving the limit for utmost iterations.
- The eventual result is global best, personal best, and its relevant position.

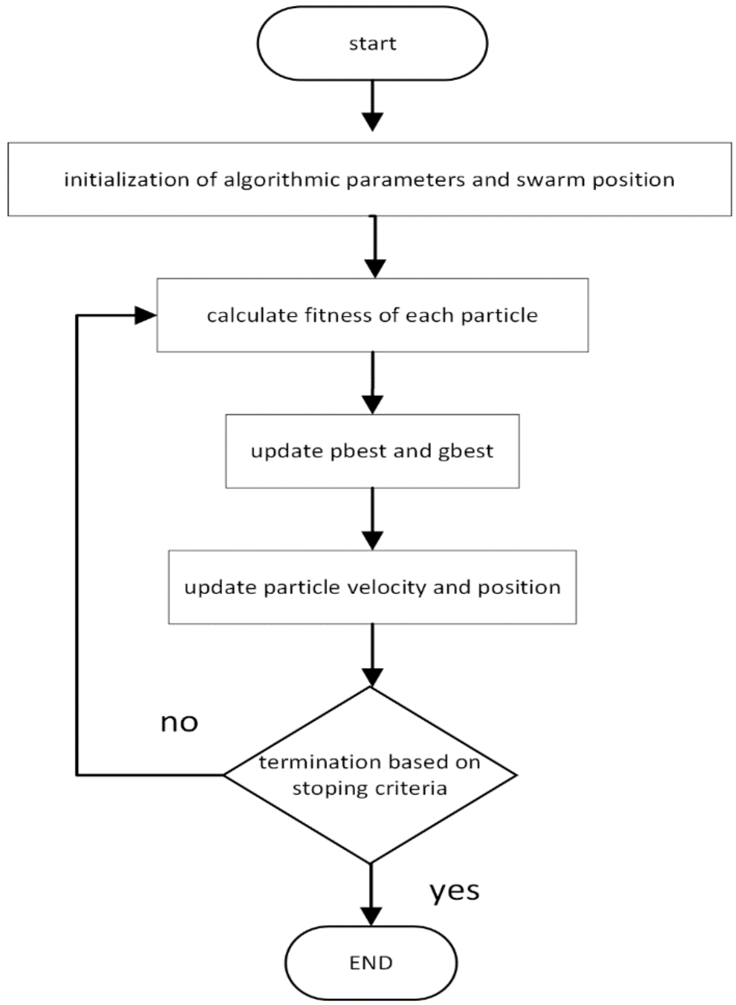



*fig 3.4 steps in PSO*

### 3.3 .2 ABC Algorithm

The problem of optimization of multi-variable numerical functions was solved in 2005 by Karabagh, he described a bee swarm algorithm called an artificial bee colony (ABC) algorithm for this purpose. The motivation for this algorithm came from the intellect and conduct of honeybee movements. This algorithm is globally used to tackle optimization issues.

While looking at the honeybee movement we came to know that in bee colony foodstuffs there are the following three performers:

i) the food sources

ii) the employed bees

iii) the unemployed bees which are separated into onlooker and scout bees.

An onlooker is a bee staying on the dance area adjudicating to choose a food source and bees that go to a food source they have beforehand sojourned are termed employed bees. A bee effectuating arbitrary exploration is named a scout. When the employed bee finds a food source it scrutinizes a food source and returns to the colony to captivate others to the food supply through a specific dance. The extent of dance determines food supply consistency, there is a greater likelihood that the onlooker bees will opt for the stronger suppliers. in the rear a food supply is deprived, the employed bee is assimilated to an escort bee that spies for a fresh supply of food. At this phase, presumptive food suppliers find a marginal cost to the colony, so it is a pivotal facet in the feeding cycle.

In the ongoing consideration, OC (Operation Cost), PTC (Pollutant Treatment Cost), and CE (Carbon Dioxide Emissions) are deemed to optimize the ED (economic dispatch). To find the food source (i.e., the optimal size of DGs) many employed bees are lobbed by the on-looker bee. At the same time the scout bee gets the same result during each iteration. Now the on-looker bee contemplates the fitness i.e., the cost function for the foremost result, and collects it in memory. After performing the number of iterations, the onlooker bee picks out the finest optimal solution during every single iteration performed. In the back nine, the scout bee finds an erratic food source (i.e., random solutions for DG size) as directed by an on-looker bee. In ABC algorithm random search is carried out by the scout bee to evade ambush in local minima for a globally optimum solution. Hence, ABC is a variegated algorithm that finds the global best optimal solution devoid of blocking in the local minima, which indicates its superior demeanor, in addition to other algorithms.

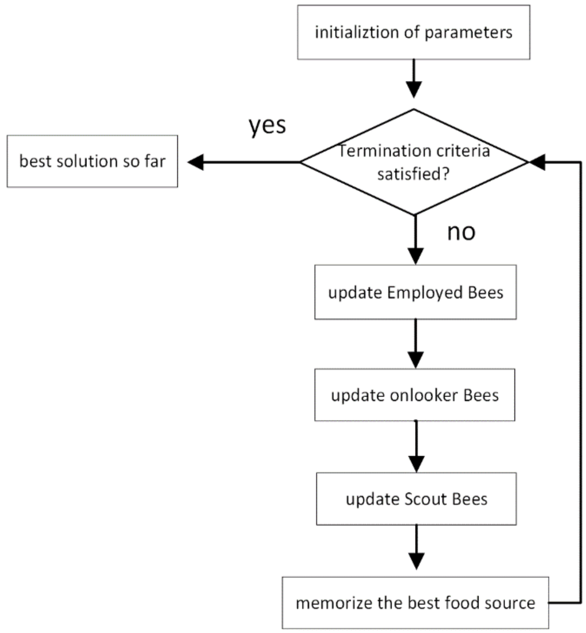



*fig 3.5 processes in ABC*

Number of food points (NFP) is the preliminary factor in ABC algorithm, and it is equivalent to the overall number of bees. Random numbers are used to create the initial population for the solution with the help of following relationship.

$$X_{i,j} = X_{j,min} + rand + (X_{j,max} - X_{j,min})$$

Where

i=1,2,3…. NFP

j=1, 2, …, J

$X_{ij}$ = $i^{th}$ population of the $j^{th}$ vector

NFP= 5

$X_{j,\ max}$ = maximum boundary of $j^{th}$ vector

$X_{j,\ min}$ = minimum boundary of $j^{th}$ vector

rand= uniformly distributed random number from 0 to 1

To symbolize the fitness function underneath mathematical statement is applied

$$Fitness_i = Obj(X_{ij}) + \sum_{m=1}^{M} \lambda_{eq,m} \left|h(X_{ij})\right|^2 + \sum_{n=1}^{N} \lambda_{ineq,n} \left|g(X_{ij}) - g_{lim})\right|^2 \quad (3.7)$$

Where,

Obj= objective function

h(Xij) = equality constraints

g(Xij) = inequality constraints

$\lambda_{eq,m}$ and $\lambda_{eq,m}$ = penalty factor which can be modified in optimization process

$g_{lim}$ can be identified as

$$g_{lim} = \begin{cases} X_j & \mathrm{Xj,min} \leq \mathrm{Xj} \leq \mathrm{Xj,max} \\ X_{j,min} & \mathrm{Xj} < \mathrm{Xj,min} \\ X_{j,max} & \mathrm{Xj} > \mathrm{Xj,max} \end{cases} \quad (3.8)$$

If one as minimum variable infringe the limits the rate of the penalty factor can be boosted and the consequent individual will, thus, be abandoned to omit the infeasible solution.

# CHAPTER 4

# SIMULATION RESULTS AND ANALYSIS

# CHAPTER 4

# Simulation results and analysis:

## Winter unscheduled load:

Winter unscheduled load is taken to examine the performance of PSO and ABC algorithms with three different tariffs i.e., TOU, RTEP and CPP.

**Autonomous 80 EV**

For autonomous 80 EVs, when Scheduling strategy-1 is chosen to be the study case for the unscheduled load to investigate the performance of PSO and ABC algorithms. Table 1 portrays parameters of PSO and proposed ABC algorithms. Looking at the cost in the table below it is shown that the cost is decreased using PSO in all tariffs. Furthermore, operating cost is high with all tariffs in ABC algorithm. Pollutant emissions and carbon dioxide emissions in case of PSO algorithm are more for all tariffs except RTEP.

In case of Scheduling strategy 3 the cost is decreased using ABC in all tariffs. Furthermore, operating cost is high with all tariffs in PSO algorithm except TOU tariff. Pollutant emissions and carbon dioxide emissions in case of PSO algorithm are more.

| Scheduling strategy | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 1 Grid Connected | C1 | 338.4341 | 327.0278 | 143.4991 | 16.8823 | 29.9566 | 26.3525 |
| | C2 | 82.5826 | 76.8011 | 385.9575 | 252.8237 | 204.2769 | 202.0569 |
| | C3 | 122.9673 | 125.5467 | 167.9701 | 158.486 | 154.0911 | 155.1416 |
| | C | 249.7883 | 241.2992 | 208.6882 | 92.6519 | 86.9472 | 85.2211 |
| 3 | C1 | 1381.59 | 1353.914 | 1324.899 | 1379.336 | 1419.789 | 1403.445 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| islanded | | 9 | 7 | 6 | 9 | 9 | 6 |
| | C2 | 88.9963 | 62.7125 | 86.0954 | 97.3945 | 104.6245 | 135.6553 |
| | C3 | 47.1089 | 42.2138 | 42.482 | 47.8855 | 51.56 | 53.8632 |
| | C | 907.999 | 883.0621 | 868.0993 | 908.8082 | 936.829 | 934.6741 |

*Table 1 Unscheduled winter load with autonomous 80 EV*

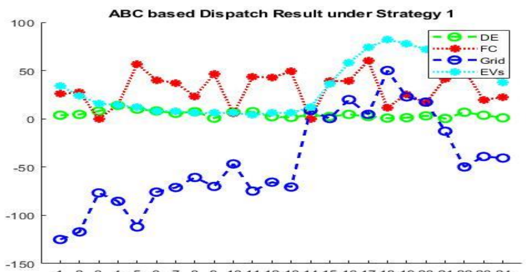



*fig 4.0.1 winter unscheduled load with CPP tariff autonomous 80 EV grid connected*

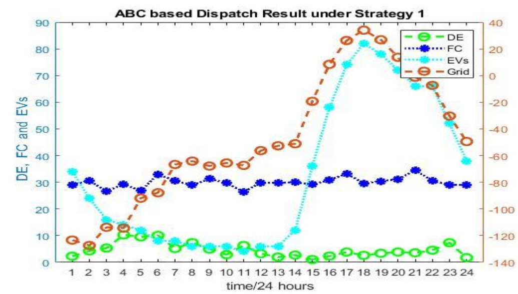



*fig 4.0.2 winter unscheduled load with CPP tariff autonomous 80 EV grid connected*

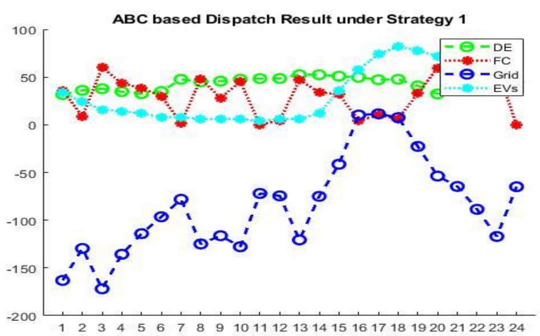



*fig 4.0.3 winter unscheduled load with RTEP tariff autonomous 80 EV grid connected*

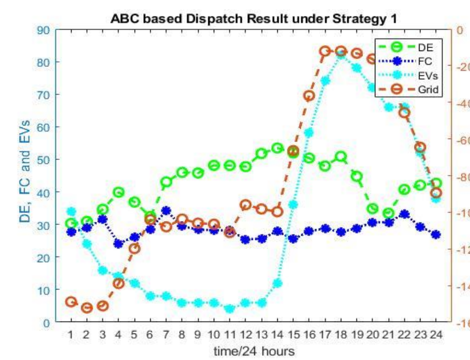
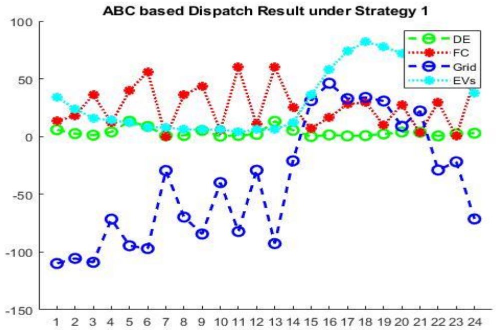



*fig 4.0.4 winter unscheduled load with RTEP tariff autonomous 80 EV grid connected*



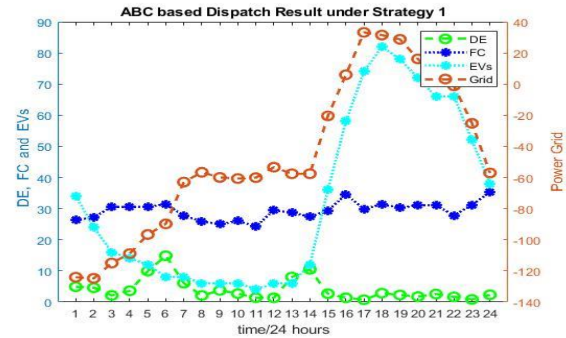
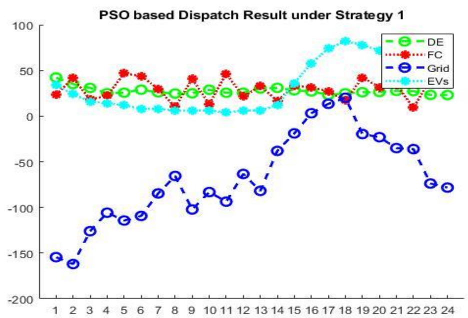




*fig 4.0.5 winter unscheduled load with TOU tariff autonomous 80 EV grid connected grid connected*

*fig 4.0.6 winter unscheduled load with TOU tariff autonomous 80 EV*



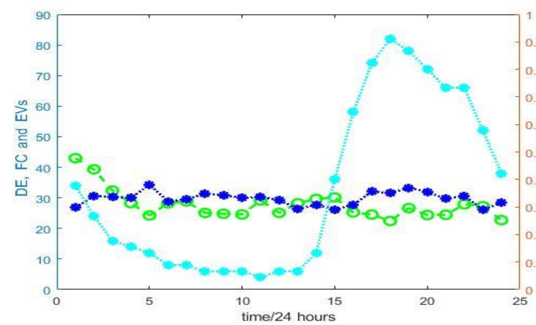
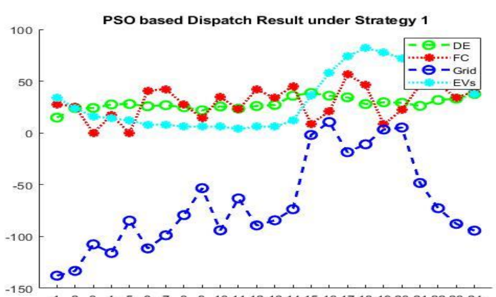




*fig 4.0.7 winter unscheduled load with CPP tariff autonomous 80 EV grid connected EV grid connected*

*fig 4.0.8 winter unscheduled load with CPP tariff autonomous 80*



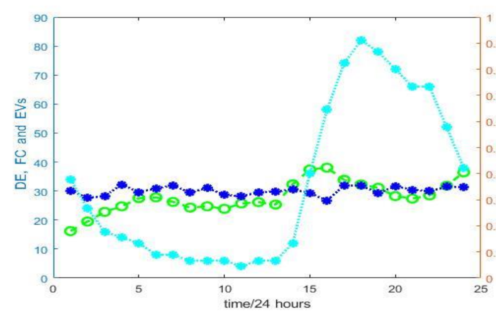




*Fig 4.0.9 winter unscheduled load with RTEP tariff autonomous 80 EV grid connected EV grid connected*

*fig 4.0.10 winter unscheduled load with RTEP tariff autonomous80*

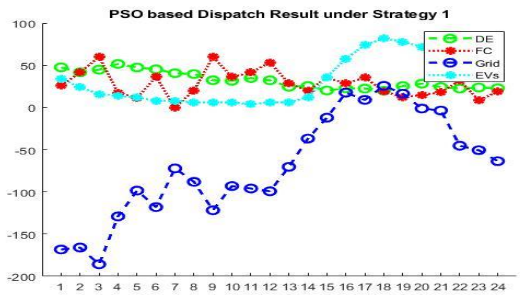



*Fig 4.0.11 winter unscheduled load with TOU tariff autonomous 80 EV grid connected grid connected*

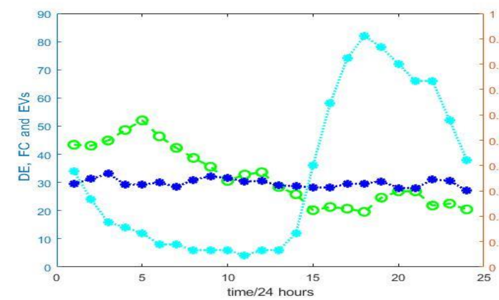



*fig 4.0.12 winter unscheduled load with TOU tariff autonomous 80 EV*

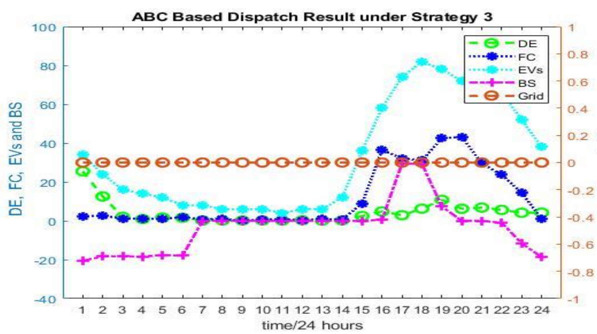



*fig 4.0.13 winter unscheduled load with CPP tariff autonomous 80 EV islanded islanded*

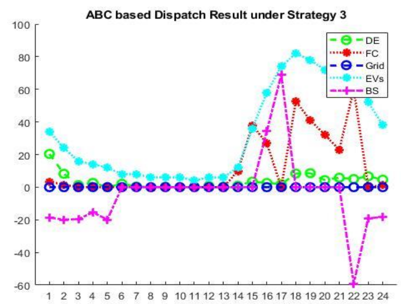



*fig 4.0.14 winter unscheduled load with CPP tariff autonomous 80 EV*

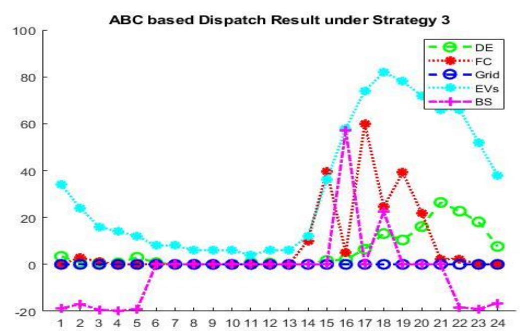



*fig 4.0.15 winter unscheduled load with RTEP tariff autonomous 80 EV islanded islanded*

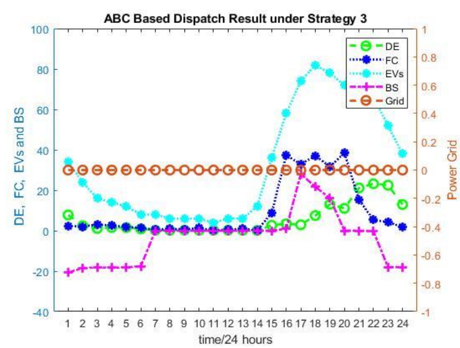
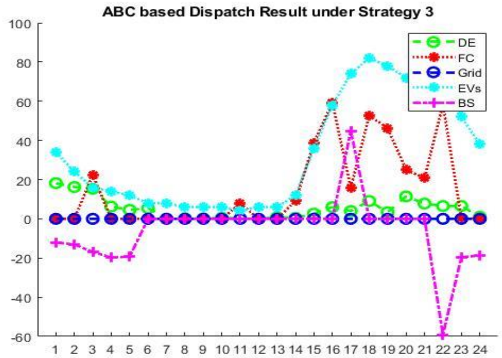



*fig 4.0.16 winter unscheduled load with RTEP tariff autonomous 80 EV*



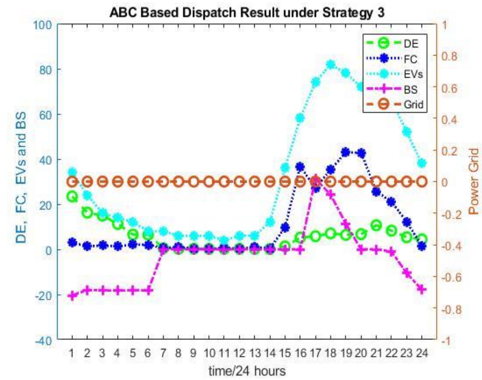
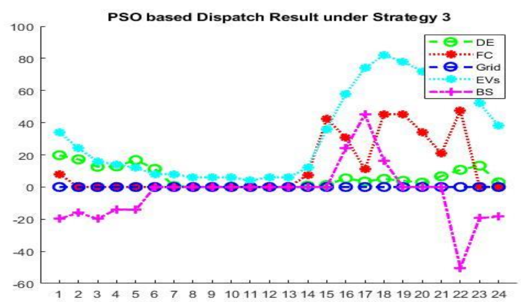




*fig 4.0.17 winter unscheduled load with TOU tariff autonomous 80 EV islanded islanded*

*fig 4.0.18 winter unscheduled load with TOU tariff autonomous 80 EV*



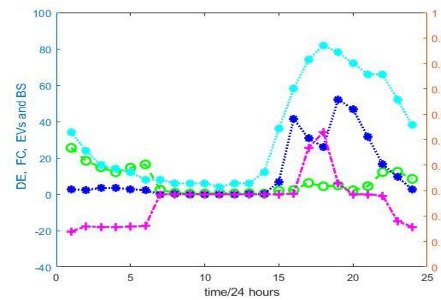
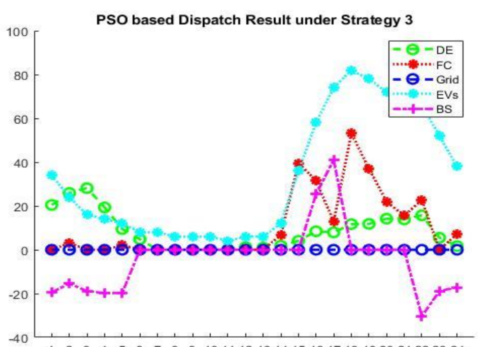




*fig 4.0.19 winter unscheduled load with CPP tariff autonomous 80 EV islanded islanded*

*fig 4.0.20 winter unscheduled load with CPP tariff autonomous 80 EV*



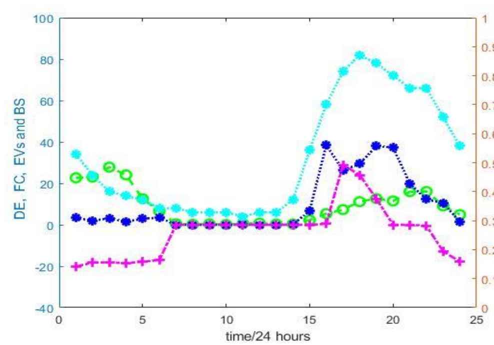




*fig 4.0.21 winter unscheduled load with RTEP tariff autonomous 80 EV islanded islanded*

*fig 4.0.22 winter unscheduled load with RTEP tariff autonomous 80 EV*

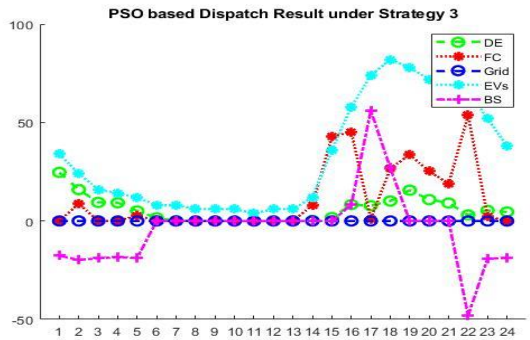



*Fig 4.0.23 winter unscheduled load with TOU tariff autonomous 80 EV islanded islanded*

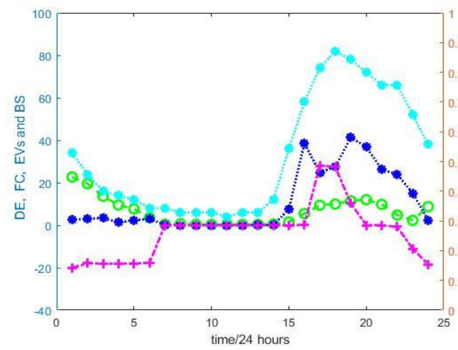



*fig 4.0.24 winter unscheduled load with TOU tariff autonomous 80 EV*

**Autonomous 500 EVs:**

For autonomous 500 EVs, when Scheduling strategy-1 is chosen to be the study case for the unscheduled load to investigate the performance of PSO and ABC algorithms. Table 2 shows parameters of PSO and proposed ABC algorithms. Looking at the cost in the table below it is shown that the cost is decreased using PSO in all tariffs except RTEP where it is increased. Furthermore, operating cost is high in PSO with TOU and RTEP tariff whereas low with CPP tariffs. Pollutant emissions and carbon dioxide emissions in case of PSO algorithm are more for CPP and RTEP respectively, else less all tariffs.

In case of Scheduling strategy 3 the cost is decreased using ABC in all tariffs. Furthermore, operating cost is high with all tariffs in PSO algorithm except CPP tariff. Pollutant emissions and carbon dioxide emissions in case of PSO with CPP tariff is less whereas are more for TOU and RTEP tariff.

| Scheduling strategy | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 1 Grid connected | C11 | 4969.778 | 5318.0594 | 5088.1464 | 5087.6275 | 4946.8422 | 5176.8697 |
| | C2 | 935.3212 | 541.6271 | 808.8778 | 776.4837 | 981.449 | 748.3432 |
| | C3 | 484.6635 | 512.7993 | 495.8583 | 493.2087 | 484.5783 | 505.1228 |
| | C | 3458.086 | 3581.1962 | 3501.9988 | 3493.0234 | 3455.3821 | 3543.8495 |
| 3 Islanded | C1 | 2753.638 | 2809.9881 | 2726.3776 | 2862.4449 | 2786.707 | 2815.7525 |
| | C2 | 496.6476 | 553.5482 | 462.0203 | 588.4948 | 506.2553 | 534.8681 |
| | C3 | 189.858 | 204.2014 | 184.0625 | 207.8192 | 193.2747 | 198.0798 |
| | C | 1902.226 | 1953.905 | 1875.3137 | 1997.1443 | 1926.134 | 1951.4965 |

*Table 2 Unscheduled winter load autonomous 500 EV*

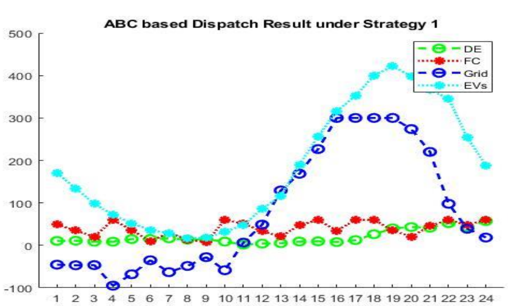



*fig 4.0.25 winter unscheduled load with CPP tariff autonomous 500 EV grid connected grid connected*

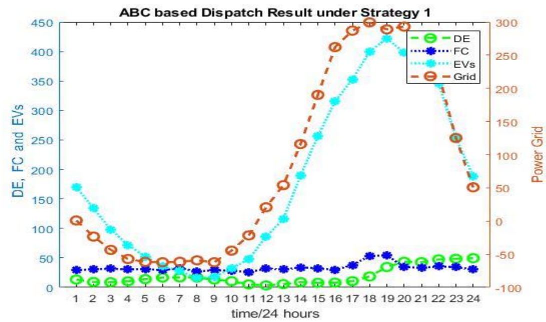
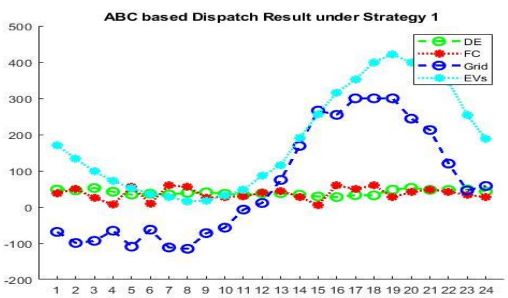



*fig 4.0.26 winter unscheduled load with CPP tariff autonomous 500 EV*



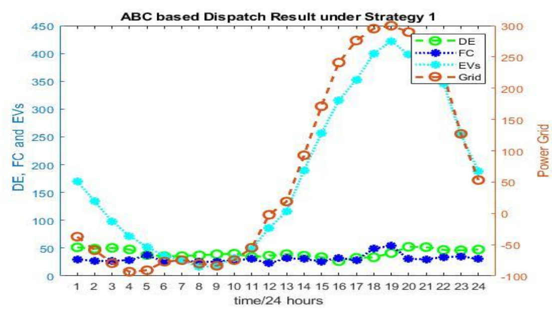
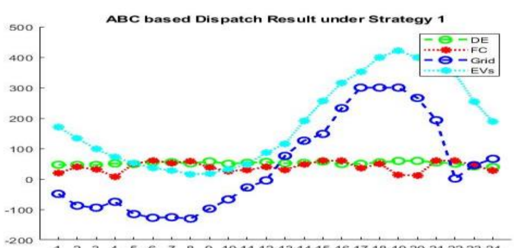




*Fig 4.0.27 winter unscheduled load with RTEP tariff autonomous 500 EV grid connected grid connected*

*fig4.0.28 winter unscheduled load with RTEP tariff autonomous 500 EV*



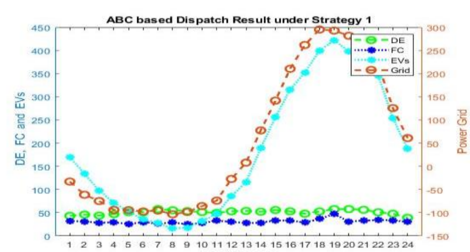




*fig 4.0.29 winter unscheduled load with TOU tariff autonomous 500 EV grid connected EV grid connected*

*fig 4.0.30 winter unscheduled load with TOU tariff autonomous 500*

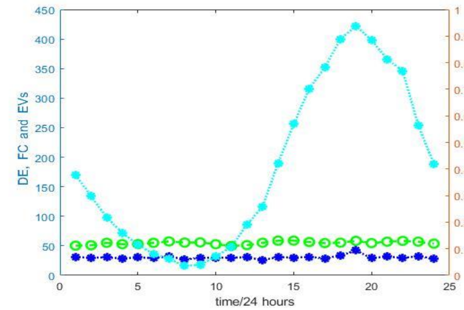
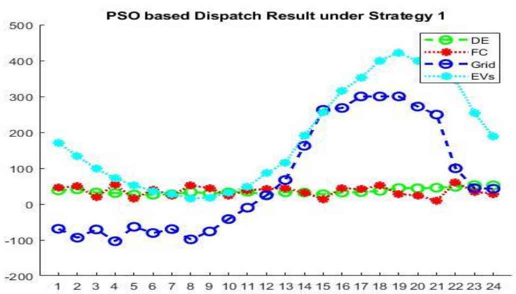




*fig 4.0.31 winter unscheduled load with CPP tariff autonomous 500 EV grid connected connected*

*fig 4.0.32 winter unscheduled load with CPP tariff autonomous 500 EV grid*



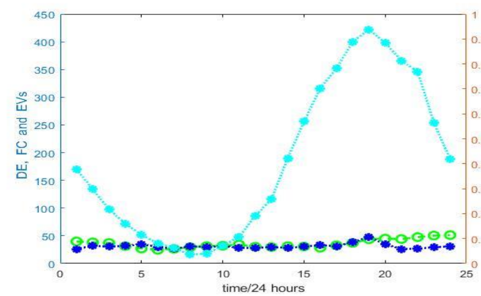
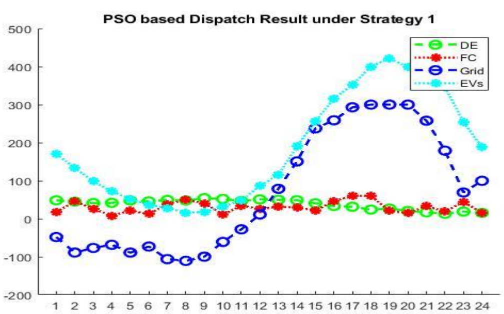




*fig 4.0.33 winter unscheduled load with RTEP tariff autonomous 500 EV grid connected grid connected PSO*

*fig 4.0.34 winter unscheduled load with RTEP tariff autonomous500 EV*



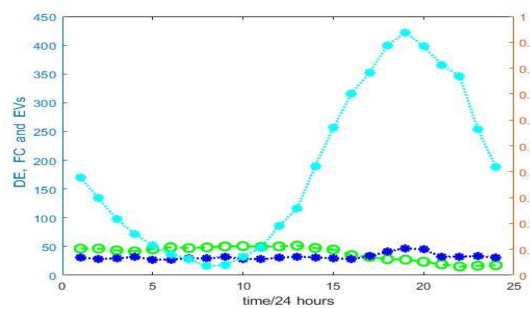




*fig 4.0.35 winter unscheduled load with TOU tariff autonomous500 EV grid connected connected PSO*

*fig 4.0.36 winter unscheduled load with TOU tariff autonomous 500 EV grid*

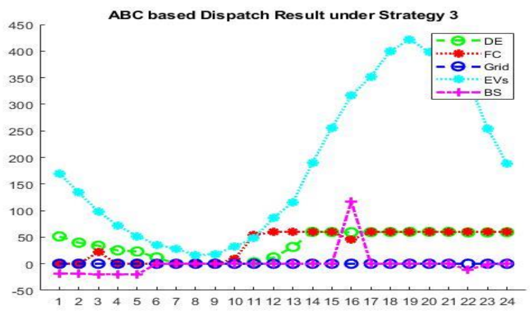



*fig 4.0.37 winter unscheduled load with CPP tariff autonomous 500 EV islanded EV islanded*

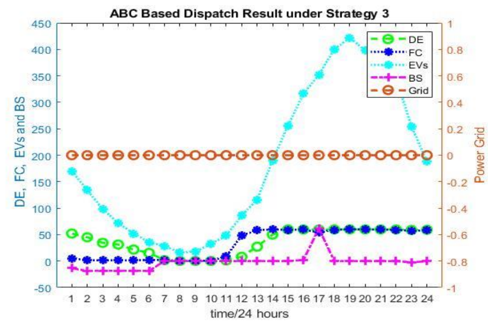



*fig 4.0.38 winter unscheduled load with CPP tariff autonomous 500*

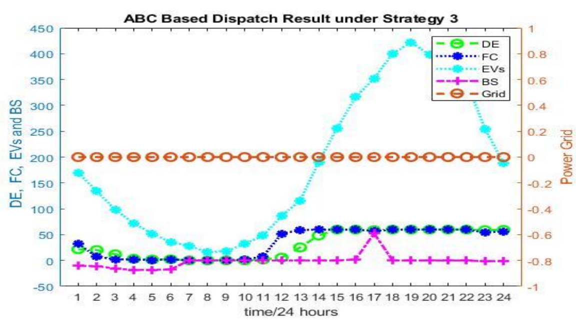



*fig 4.0.39 winter unscheduled load with RTEP tariff autonomous 500 EV islanded EV islanded*

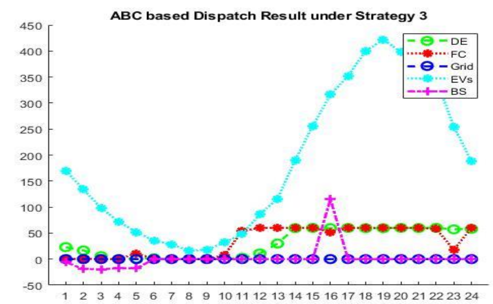



*fig 4.0.40 winter unscheduled load with RTEP tariff autonomous 500*

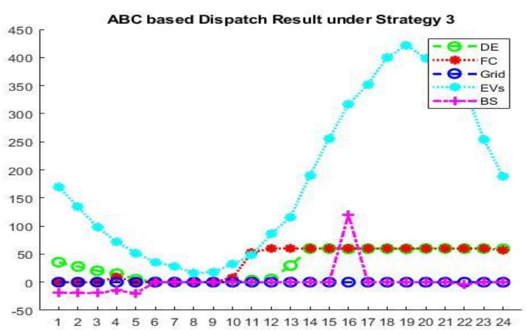



*fig 4.0.41 winter unscheduled load with TOU tariff autonomous 500 EV islanded islanded*

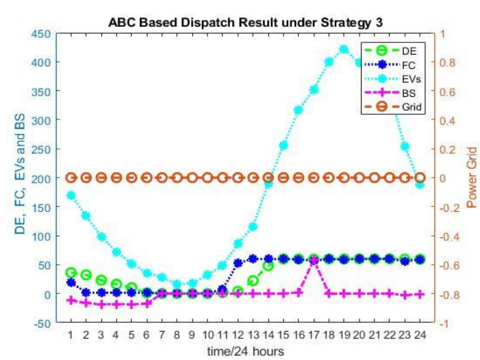
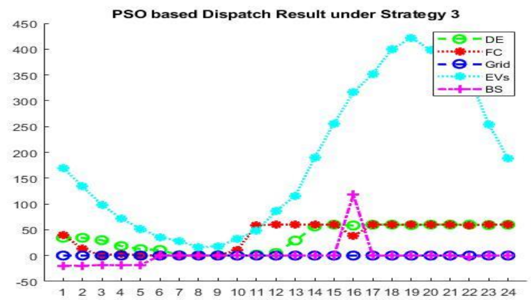



*fig 4.0.42 winter unscheduled load with TOU tariff autonomous 500 EV*



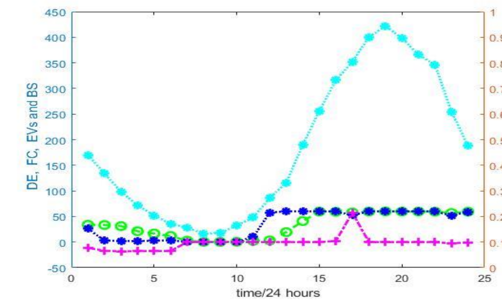
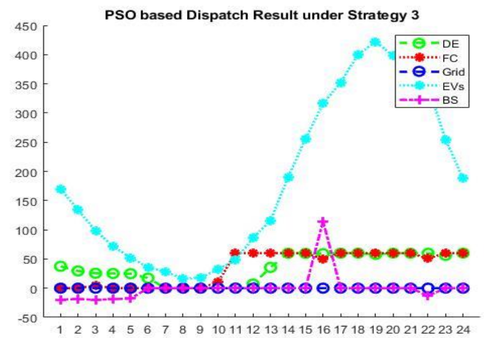




*fig 4.0.43 winter unscheduled load with CPP tariff autonomous 500 EV islanded islanded*

*fig 4.0.44 winter unscheduled load with CPP tariff autonomous 500 EV*



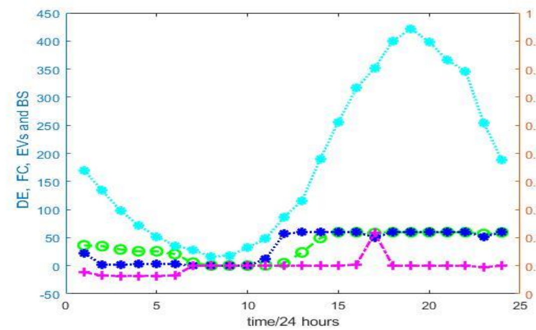
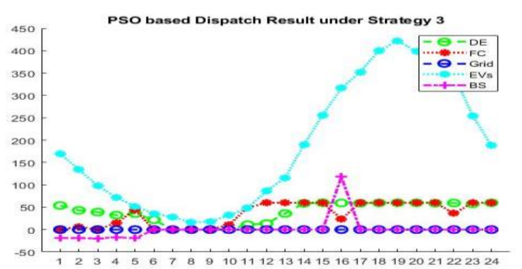




*fig 4.0.45 winter unscheduled load with RTEP tariff autonomous 50 EV islanded PSO islanded PSO*

*fig 4.0.46 winter unscheduled load with RTEP tariff autonomous 500 EV*



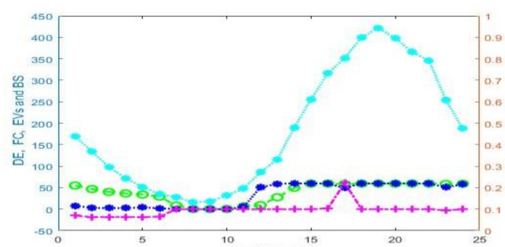




*fig 4.0.47 winter unscheduled load with TOU tariff autonomous 500 EV islanded islanded*

*fig 4.0.48 winter unscheduled load with TOU tariff autonomous 500 EV*

**Coordinated 80 EVs**

For coordinated 80 EVs, when Scheduling strategy 2 is picked to be the review case for the unscheduled load to examine the performance of PSO and ABC algorithms. Table 3 portrays parameters of PSO and proposed ABC algorithms. Looking at the cost in the table below it is shown that the cost is decreased using PSO in TOU and RTEP tariffs whereas increased in CPP. Furthermore, operating cost is high with CPP and RTEP tariffs in PSO algorithm. Pollutant emissions are less for PSO algorithm and carbon dioxide emissions for CPP are increased and decreased in RTEP. In case of TOU tariff CO2 emissions are approximately same for both algorithms

In case of Scheduling strategy 4 the cost is increased using ABC in CPP tariff otherwise decreased. Furthermore, operating cost is high with TOU and RTEP tariffs in PSO algorithm. Pollutant emissions and carbon dioxide emissions in case of PSO algorithm are more with TOU and RTEP and less with CPP tariff.

| Scheduling strategy | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 2 Grid connected | C1 | 865.843 | 638.5052 | 939.6347 | 834.1511 | 826.3483 | 744.5621 |
| | C2 | 104.3318 | 126.9287 | 165.4494 | 34.8281 | 22.4294 | 44.8285 |
| | C3 | 266.6632 | 245.3282 | 273.3851 | 266.5475 | 266.6298 | 257.9404 |
| | C | 605.3773 | 465.1993 | 669.9063 | 564.6767 | 564.0935 | 511.8384 |
| 4 Islanded | C1 | 2753.6328 | 2809.9881 | 2726.3776 | 2862.4449 | 2786.707 | 2815.7525 |
| | C2 | 496.6476 | 553.5482 | 462.0203 | 588.4948 | 506.2553 | 534.8681 |
| | C3 | 189.858 | 204.2014 | 184.0625 | 207.8192 | 193.2747 | 198.0798 |
| | C | 1902.2263 | 1953.905 | 1875.3137 | 1997.1443 | 1926.134 | 1951.4965 |

*Table 3 Unscheduled winter load coordinated 80 EV*

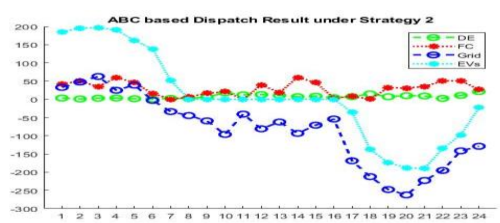



*fig 4.0.49 winter unscheduled load with CPP tariff coordinated 80 EV grid connected connected*

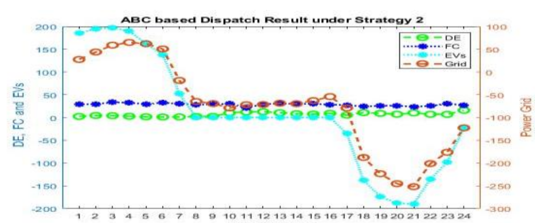



*fig 4.0.50 winter unscheduled load with CPP tariff coordinated 80 EV grid*

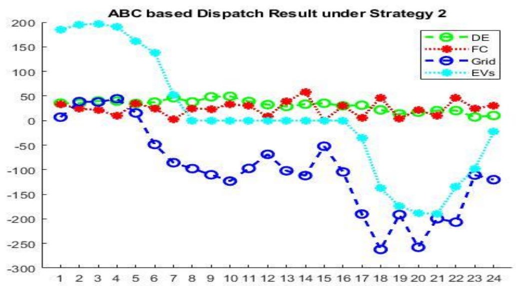



*fig 4.0.51 winter unscheduled load with RTEP tariff coordinated 80 EV grid connected grid connected*

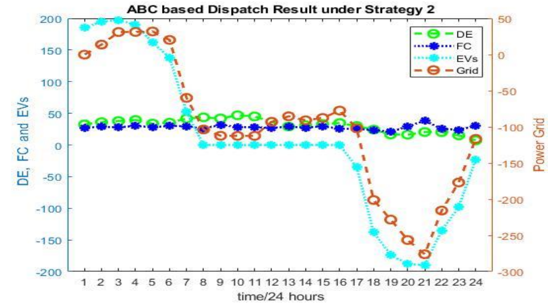



*fig 4.0.52 winter unscheduled load with RTEP tariff coordinated 80 EV*

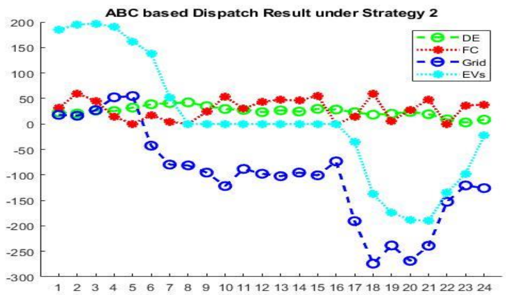



*fig 4.0.53 winter unscheduled load with TOU tariff coordinated 80 EV grid connected connected*

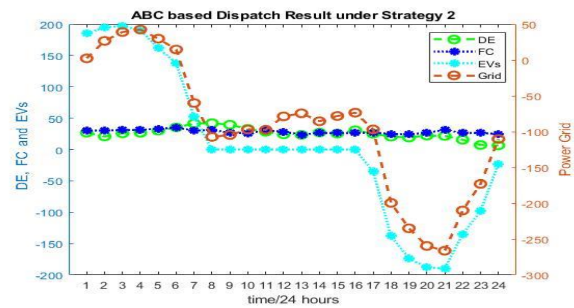
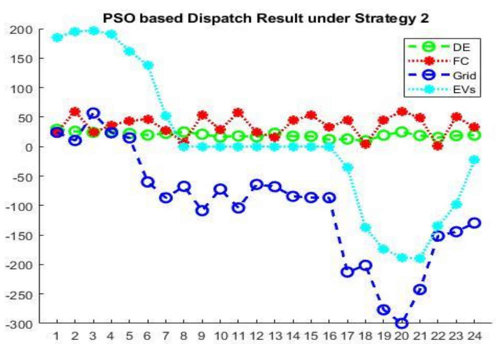



*fig 4.0.54 winter unscheduled load with TOU tariff coordinated 80 EV grid*



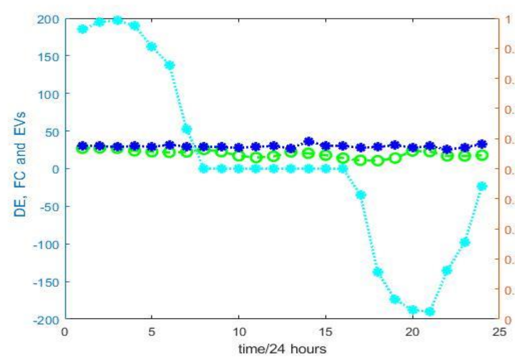
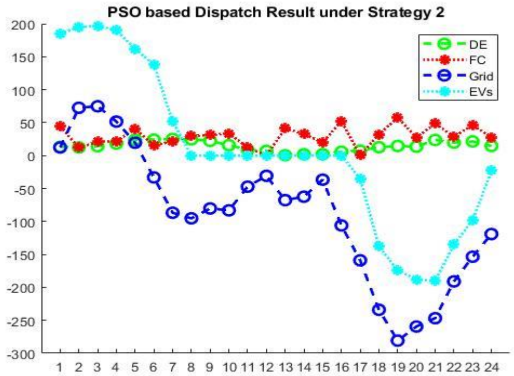




*fig 4.0.55 winter unscheduled load with CPP tariff coordinated 80 EV grid connected grid connected*

*fig 4.0.56 winter unscheduled load with CPP tariff coordinated 80 EV*



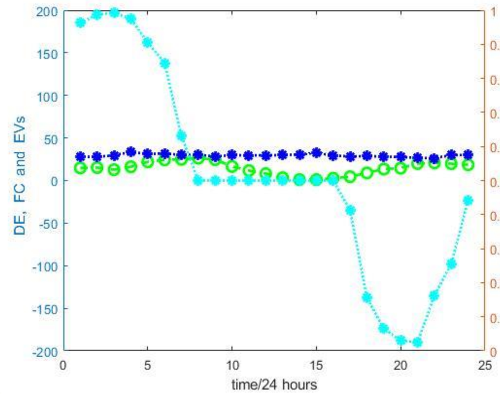
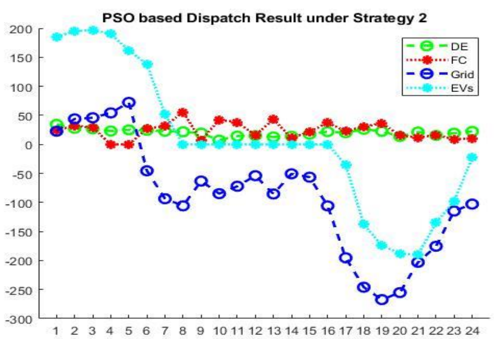




*fig 4.0.57 winter unscheduled load with RTEP tariff coordinated 80 EV grid connected grid connected*

*fig 4.0.58 winter unscheduled load with RTEP tariff coordinated 80 EV*



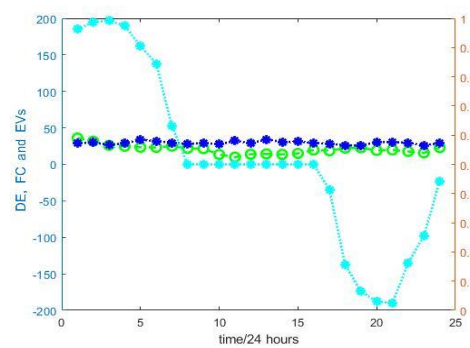
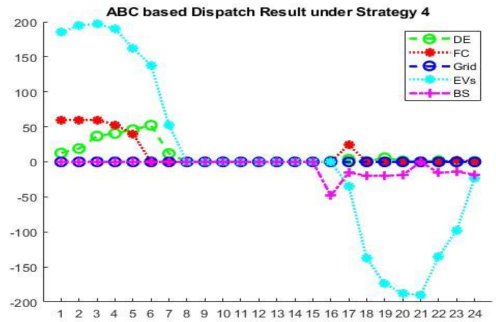




*fig 4.0.59 winter unscheduled load with TOU tariff coordinated 80 EV islanded islanded*

*fig 4.0.60 winter unscheduled load with TOU tariff coordinated 80 EV*



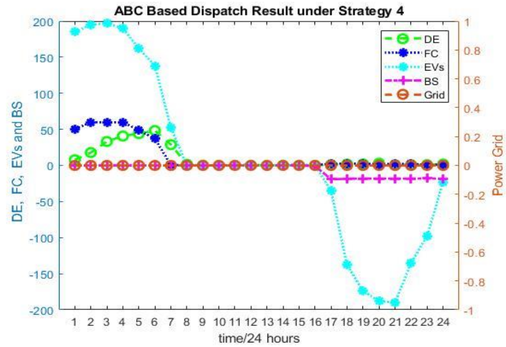
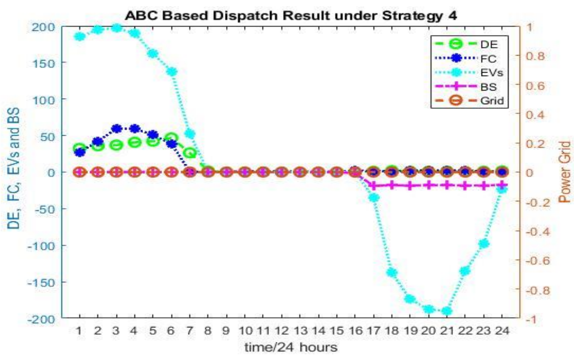




*fig 4.0.61 winter unscheduled load with CPP tariff coordinated 80 EV islanded islanded*

*fig 4.0.62 winter unscheduled load with CPP tariff coordinated 80 EV*



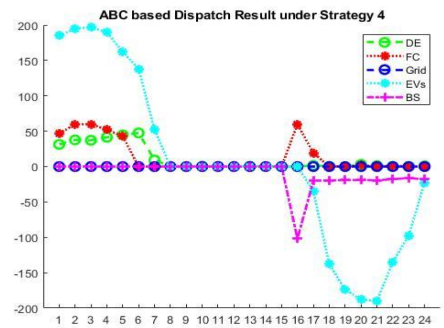
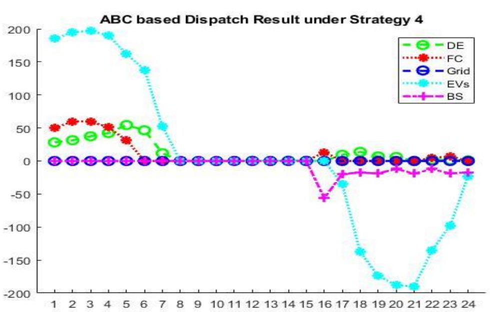




*fig 4.0.63 winter unscheduled load with RTEP tariff coordinated 80 EV islanded EV islanded*

*fig 4.0.64 winter unscheduled load with RTEP tariff coordinated 80*



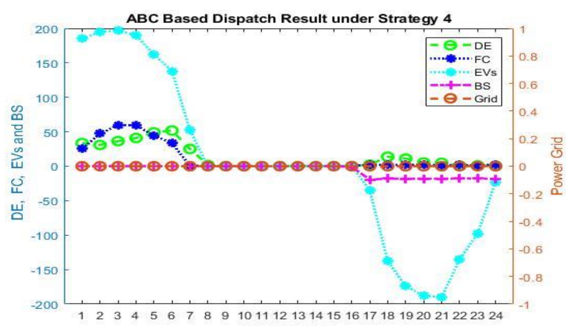
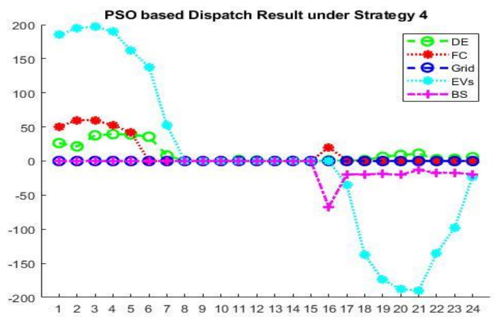




*fig 4.0.65 winter unscheduled load with TOU tariff coordinated 80 EV islanded islanded*

*fig 4.0.66 winter unscheduled load with TOU tariff coordinated 80 EV*



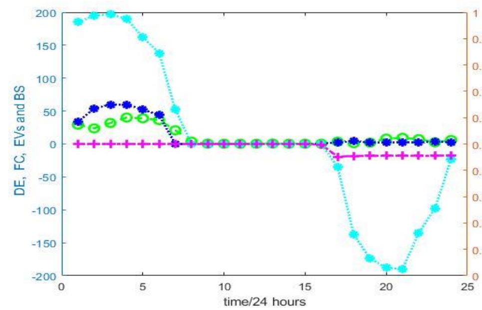
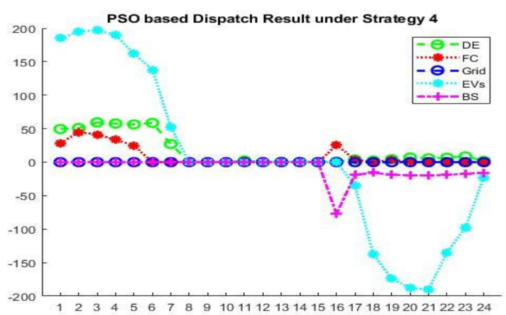




*fig 4.0.67 winter unscheduled load with CPP tariff coordinated 80 EV islanded islanded*

*fig 4.0.68 winter unscheduled load with CPP tariff coordinated 80 EV*



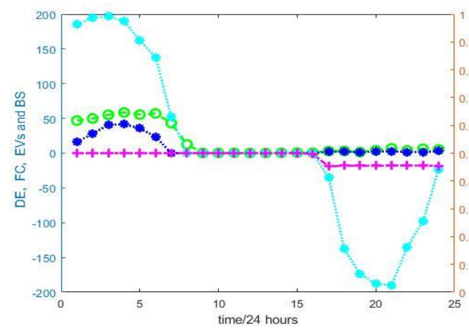
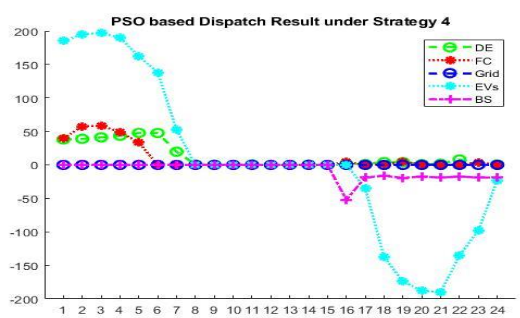




*fig 4.0.69 winter unscheduled load with RTEP tariff coordinated 80 EV islanded islanded*

*fig 4.0.70 winter unscheduled load with RTEP tariff coordinated 80 EV*



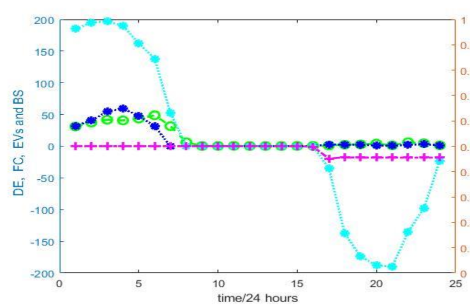




*fig 4.0.71 winter unscheduled load with TOU tariff coordinated 80 EV islanded islanded*

*fig 4.0.72 winter unscheduled load with TOU tariff coordinated 80 EV*

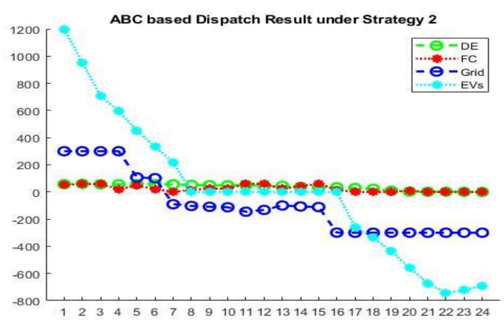
## Coordinated 500 EVs

Given below is the table for coordinated 500 EVs, when Scheduling strategy-2 is selected to investigate the performance of PSO and ABC algorithms for unscheduled load. Looking at the cost in the table below it is shown that the cost is decreased using PSO in all tariffs. Moreover, operating cost is high with all tariffs in PSO algorithm. Pollutant emissions are more, and carbon dioxide emissions are less in case of PSO algorithm for all tariffs.

In case of scheduling strategy 4 the cost is decreased using ABC in all tariffs. Furthermore, operating cost for all tariffs is high in PSO algorithm. Pollutant emissions and carbon dioxide emissions are more in case of PSO algorithm.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 2 Grid connected | C1 | 356.3222 | 284.6762 | 314.6516 | 386.0925 | 535.2299 | 376.8148 |
| | C2 | 322.2007 | 365.8469 | 414.1664 | 453.0715 | 525.4256 | 428.4876 |
| | C3 | 102.3568 | 109.3645 | 103.9982 | 96.8414 | 76.8921 | 99.4525 |
| | C | 324.9184 | 287.2875 | 317.2677 | 373.1086 | 484.7095 | 361.1221 |
| 4 Islanded | C1 | 1923.8285 | 1924.0857 | 1935.2669 | 1966.0508 | 1977.2194 | 1962.3347 |
| | C2 | 293.574 | 294.1049 | 298.7868 | 318.5441 | 326.0253 | 317.0734 |
| | C3 | 108.3737 | 108.1676 | 109.7662 | 114.1528 | 115.7792 | 113.7253 |
| | C | 1312.6556 | 1314.3871 | 1321.4342 | 1346.6061 | 1355.8232 | 1343.8143 |

*Table 4 Unscheduled winter load coordinated 500 EV*



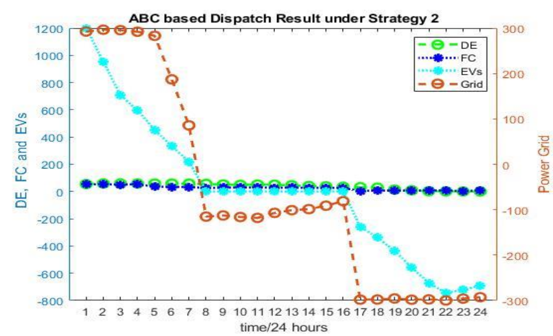
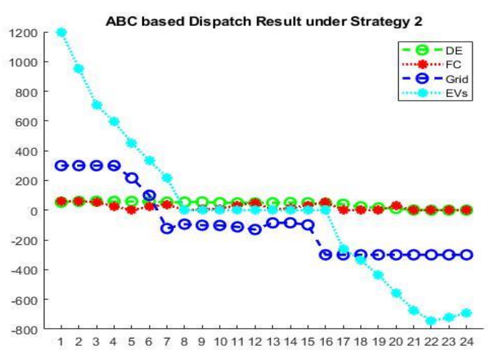




*fig 4.0.73 winter unscheduled load with CPP tariff coordinated 500 EV grid connected grid connected*

*fig 4.0.74 winter unscheduled load with CPP tariff coordinated 500 EV*



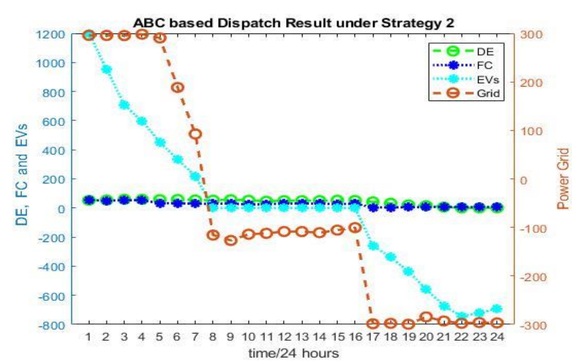



*fig 4.0.75 winter unscheduled load with RTEP tariff coordinated 500 EV grid connected EV grid connected*

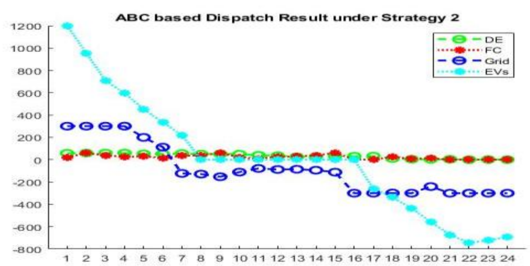



*fig 4.0.76 winter unscheduled load with RTEP tariff coordinated 500*

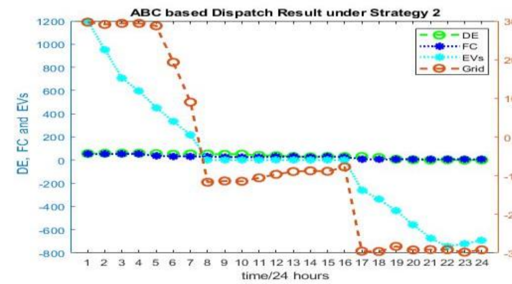



*fig 4.0.77 winter unscheduled load with TOU tariff coordinated 500 EV grid connected grid connected*

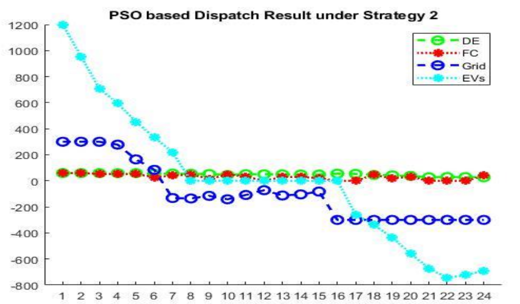



*fig 4.0.78 winter unscheduled load with TOU tariff coordinated 500 EV*

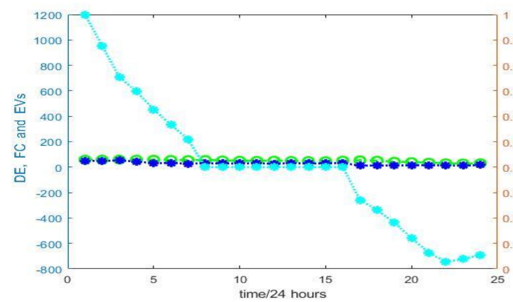



*fig 4.0.79 winter unscheduled load with CPP tariff coordinated 500 EV grid connected EV grid connected*

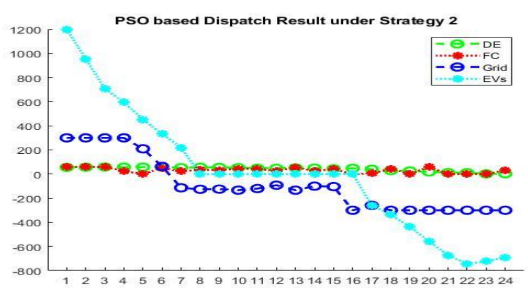



*fig 4.0.80 winter unscheduled load with CPP tariff coordinated 500*

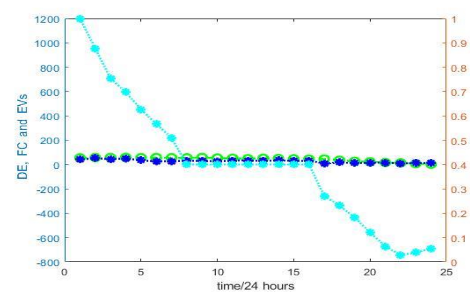



*fig 4.0.81 winter unscheduled load with RTEP tariff coordinated 500 EV grid connected grid connected*

*fig 4.0.82 winter unscheduled load with RTEP tariff coordinated 500 EV*

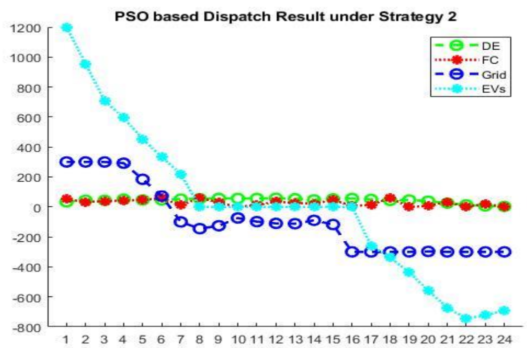



*fig 4.0.83 winter unscheduled load with TOU tariff coordinated 500 EV grid connected grid connected*

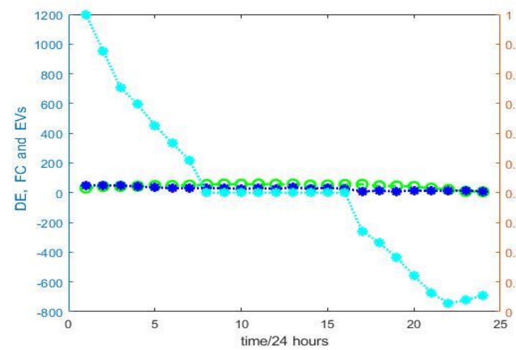



*fig 4.0.84 winter unscheduled load with TOU tariff coordinated 500 EV*

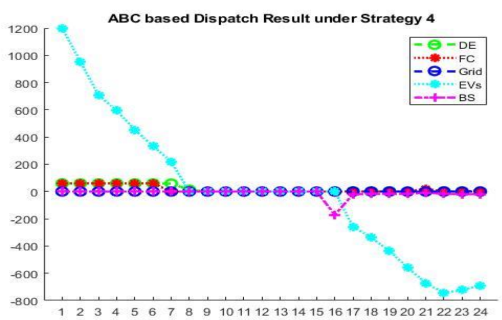



*fig 4.0.85 winter unscheduled load with CPP tariff coordinated 500 EV grid connected grid connected*

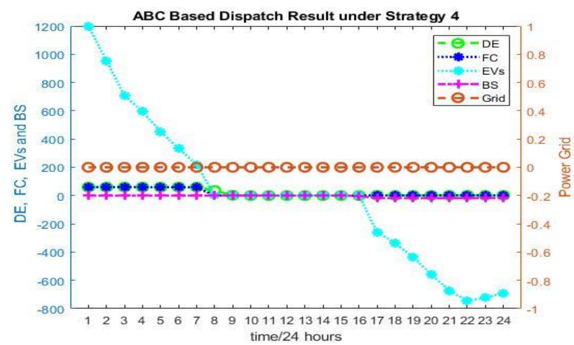



*fig 4.0.86 winter unscheduled load with CPP tariff coordinated 500 EV*

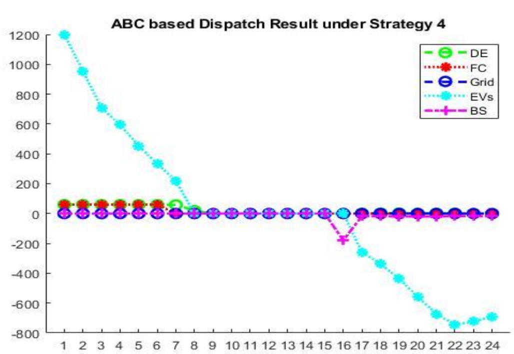



*fig 4.0.87 winter unscheduled load with RTEP tariff coordinated 500 EV islanded EV islanded*

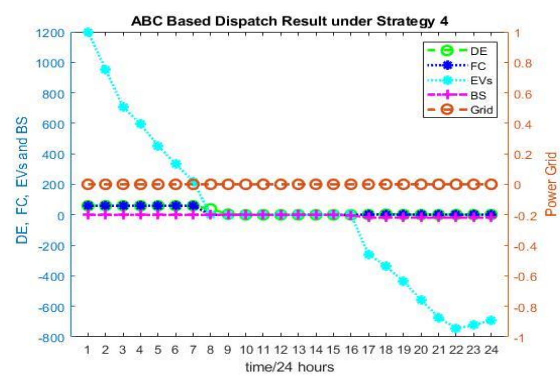



*fig 4.0.88 winter unscheduled load with RTEP tariff coordinated 500*

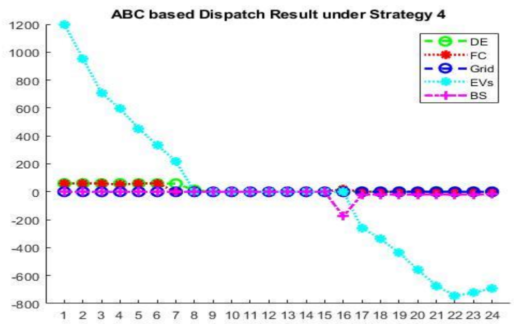



*fig 4.0.89 winter unscheduled load with TOU tariff coordinated 500 EV islanded EV islanded*

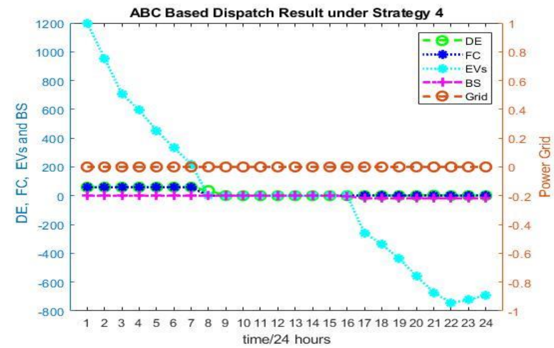



*fig 4.0.90 winter unscheduled load with TOU tariff coordinated 500*

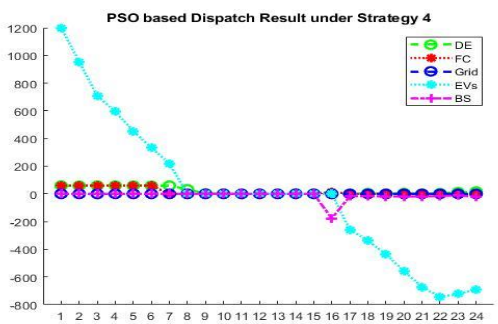



*fig 4.0.91 winter unscheduled load with CPP tariff coordinated 500 EV islanded 500 EV islanded*

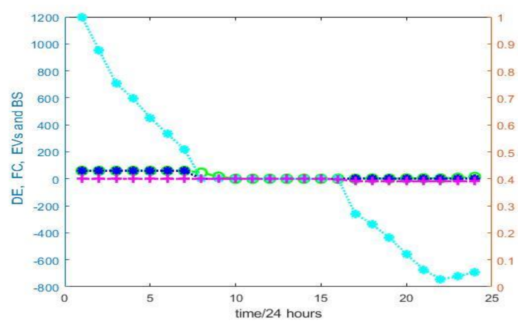
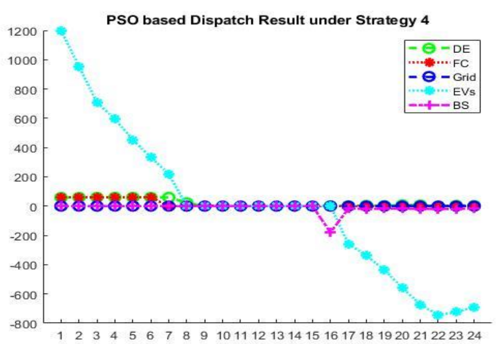



*fig 4.0.92 winter unscheduled load with CPP tariff coordinated*



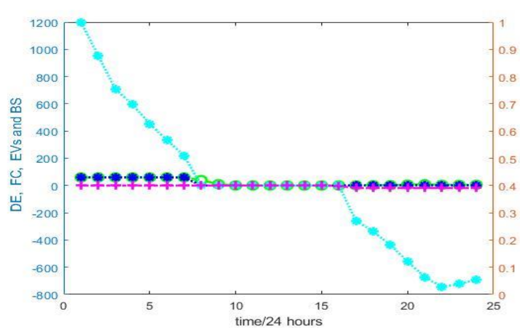




*fig 4.0.93 winter unscheduled load with RTEP tariff coordinated 500 EV islanded EV islanded*

*fig 4.0.94 winter unscheduled load with RTEP tariff coordinated 500*

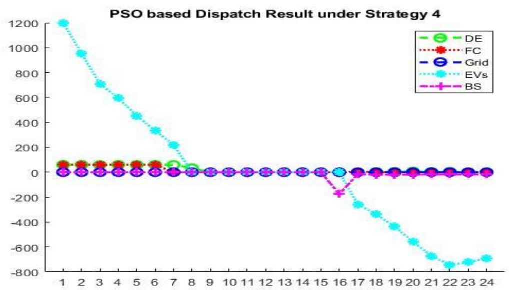



*fig 4.0.95 winter unscheduled load with TOU tariff coordinated 500 EV islanded 500 EV islanded*

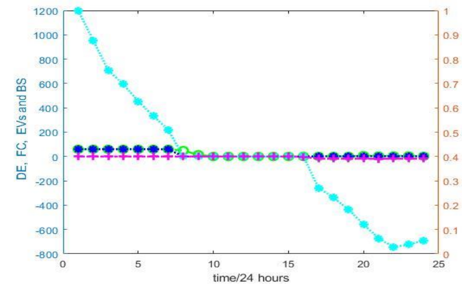



*fig 4.0.96 winter unscheduled load with TOU tariff coordinated*

**Scheduled winter load:**

Winter load is taken to examine the performance of PSO and ABC algorithms with three different tariffs i.e., TOU, RTEP and CPP.

**Autonomous 80 EVs:**

For autonomous 80 EVs, when scheduling strategy-1 is chosen to be the study case for the load to investigate the performance of PSO and ABC algorithms. Table 5 portrays parameters of PSO and proposed ABC algorithms. Looking at the cost in the table below it is shown that the cost is decreased using PSO in all tariffs. Furthermore, operating cost is high with all tariffs in ABC algorithm except RTEP. Looking at PSO algorithm in give table it is seen that Pollutant emissions are less for all tariffs however carbon dioxide emissions are more for CPP tariff.

In case of scheduling strategy 3 the cost is decreased using ABC in TOU tariff only. Furthermore, operating cost is high with all tariffs in PSO algorithm except TOU tariff. Pollutant emissions are high for PSO algorithm and carbon dioxide emissions are more for just RTEP in case of PSO algorithm.

| Scheduling scheme | quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 1 Grid connected | C1 | 222.6368 | 75.0009 | 104.9629 | 218.7307 | 73.3341 | 183.4489 |
| | C2 | 466.6012 | 181.3212 | 157.4492 | 17.19 | 165.8362 | 57.6033 |
| | C3 | 174.9461 | 145.8605 | 144.8818 | 136.6316 | 154.1828 | 139.5525 |
| | C | 284.6596 | 109.8824 | 122.6996 | 158.077 | 105.2735 | 146.347 |
| 3 Islanded | C1 | 1362.2419 | 1312.1734 | 1333.4206 | 1313.1809 | 1381.513 | 1552.9129 |
| | C2 | 73.431 | 46.8013 | 101.1211 | 79.7227 | 101.5203 | 236.185 |
| | C3 | 44 | 37.4795 | 45.046 | 41.2238 | 48.5 | 75.6753 |
| | C | 891.3221 | 851.8673 | 884.2248 | 861.4047 | 911.3244 | 1058.1353 |

*Table 5 Winter load autonomous 80 EV*

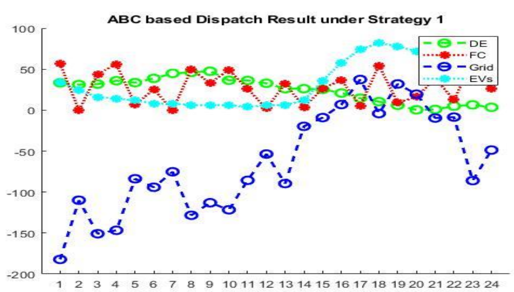



*fig 4.0.97 winter CPP load with CPP tariff autonomous 80 EV grid connected connected*

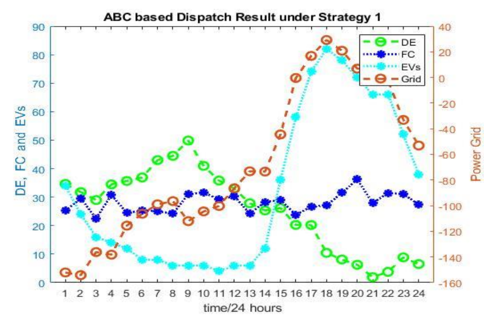



*fig 4.0.98 winter CPP load with CPP tariff autonomous 80 EV grid*

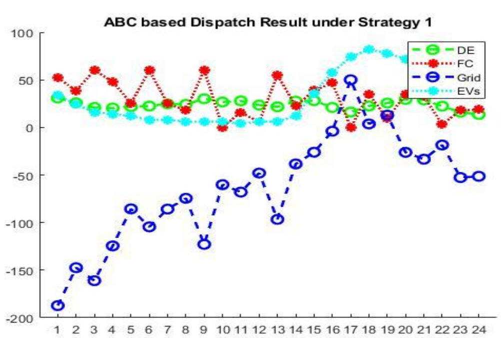



*fig 4.0.99 winter RTEP load with RTEP tariff autonomous 80 EV grid connected connected*

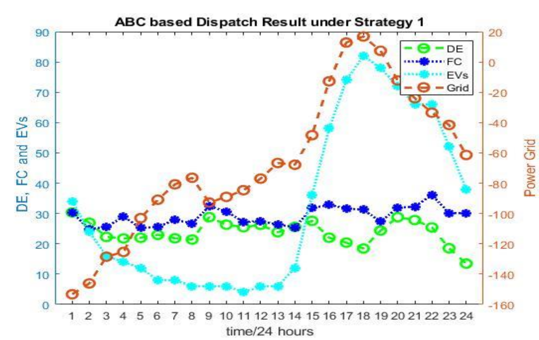
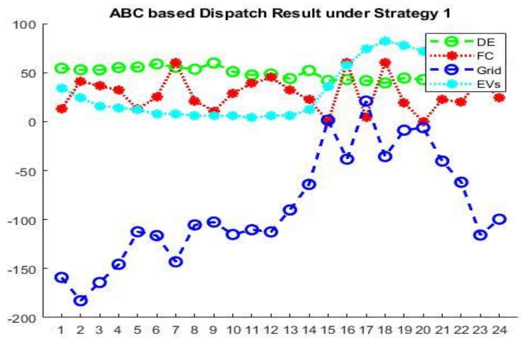



*fig 4.0.100 winter RTEP load with RTEP tariff autonomous 80 EV grid*



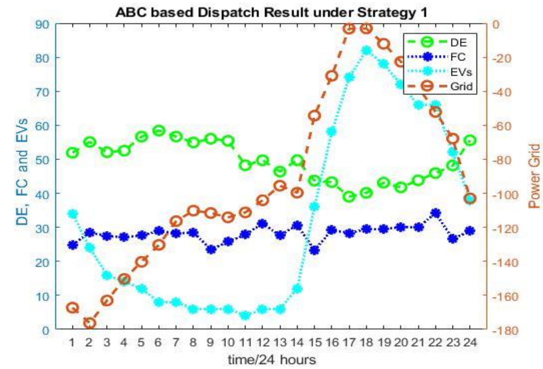
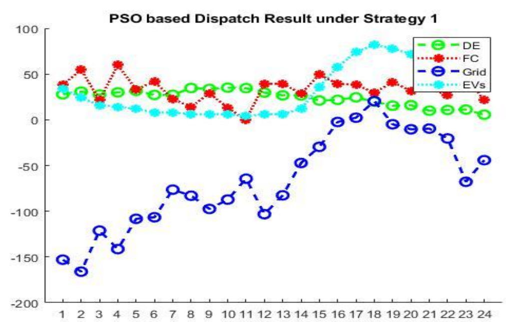




*fig 4.0.101 winter TOU load with TOU tariff autonomous 80 EV grid connected connected*

*fig 4.0.102 winter TOU load with TOU tariff autonomous 80 EV grid*



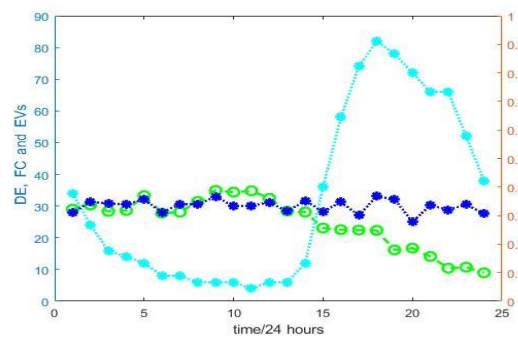
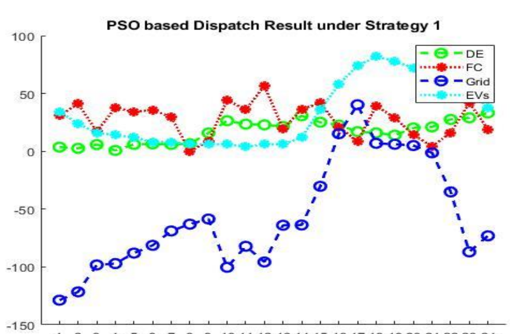




*fig 4.0.103 winter load with CPP tariff autonomous 80 EV grid connected PSO PSO*

*fig 4.0.104 winter load with CPP tariff autonomous 80 EV grid connected*



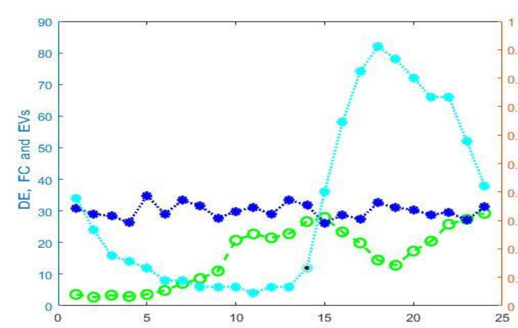
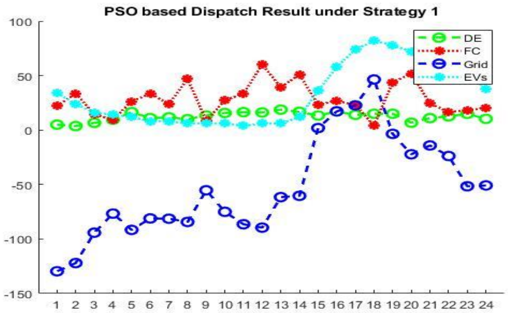



*fig 4.0.105 winter load with RTEP tariff autonomous 80 EV grid connected PSO PSO*

*fig 0.106 winter load with RTEP tariff autonomous 84 EV grid connected*



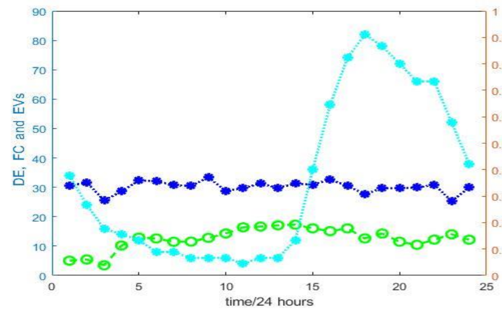
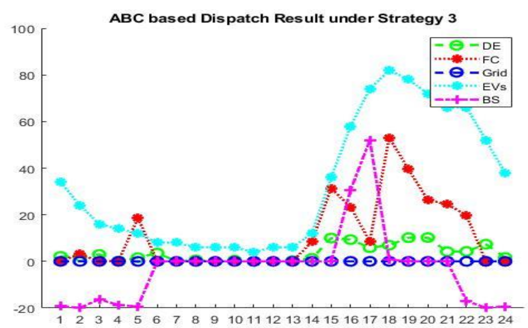




*fig 4.0.107 winter load with TOU tariff autonomous 80 EV grid connected PSO*

*fig 4.0.108 winter load with TOU tariff autonomous 80 EV grid connected PSO*



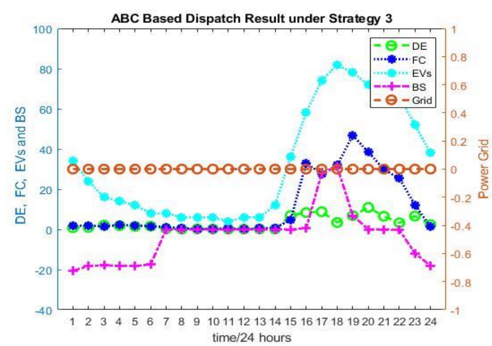
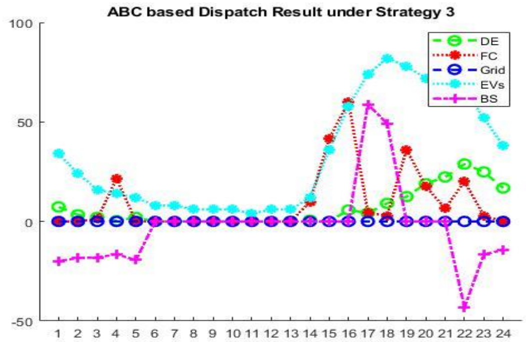




*fig 4.0.109 winter CPP load with CPP tariff autonomous 80 EV islanded*

*fig 4.0.110 winter CPP load with CPP tariff autonomous 80 EV islanded*



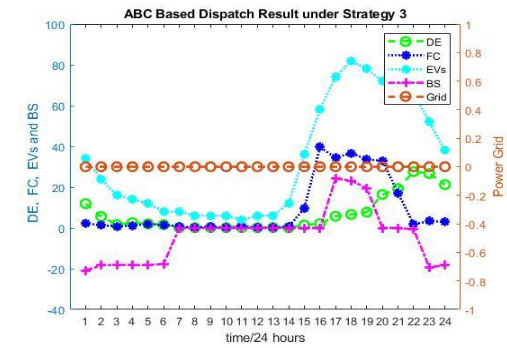
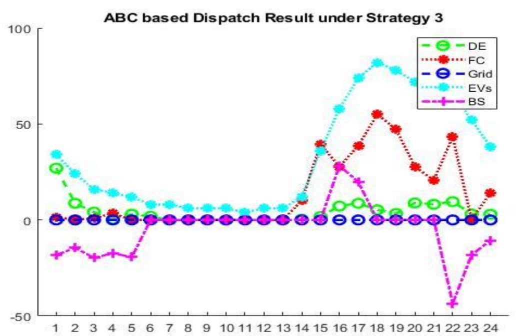




*fig 0.111 winter RTEP load with RTEP tariff autonomous 84 EV islanded*

*fig 0.112 winter RTEP load with RTEP tariff autonomous 84 EV islanded*



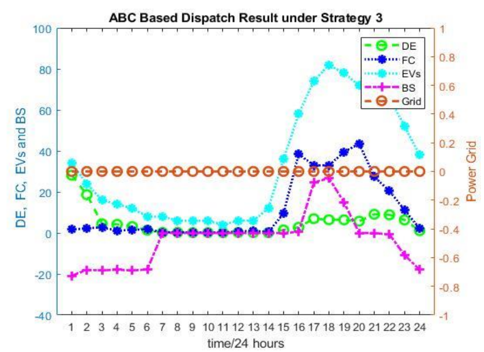
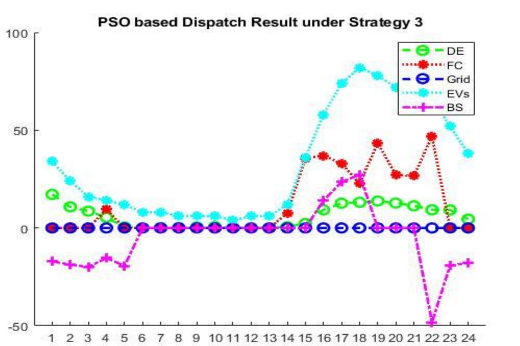




*fig 0.113 winter TOU load with TOU tariff autonomous 84 EV islanded*

*fig 0.114 winter TOU load with TOU tariff autonomous 84 EV islanded*



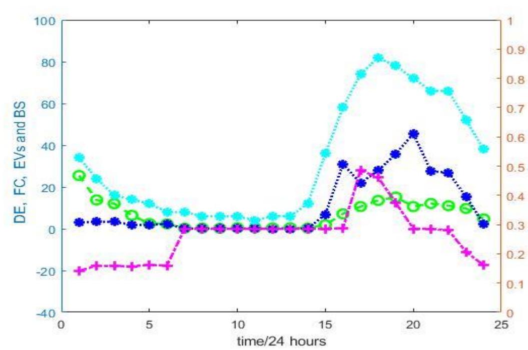
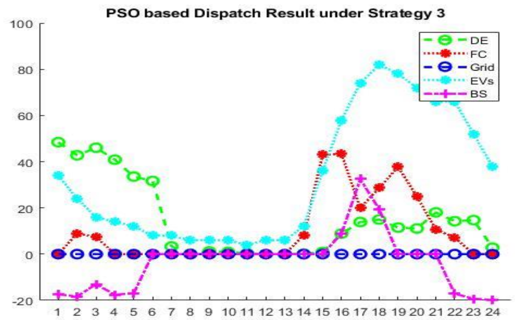




*fig 0.115 winter load with CPP tariff autonomous 84 EV islanded PSO*

*fig 0.116 winter load with CPP tariff autonomous 84 EV islanded PSO*



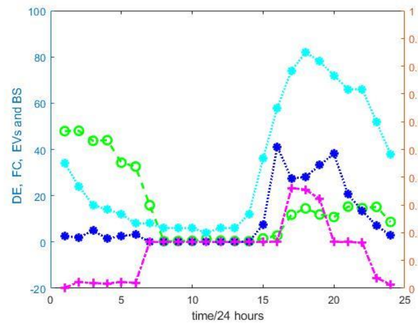
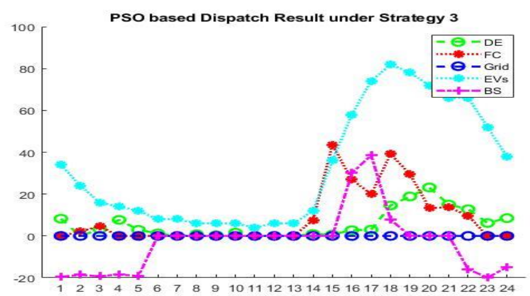




*fig 0.117 winter load with RTEP tariff autonomous 84 EV islanded PSO*

*fig 0.118 winter load with RTEP tariff autonomous 84 EV islanded PSO*



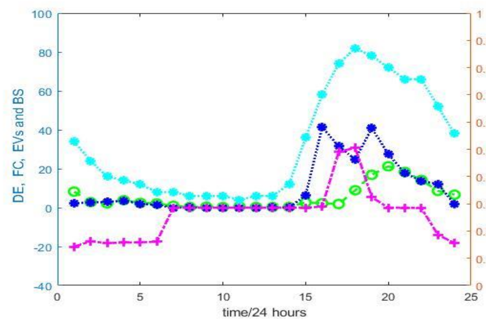




*fig 0.119 winter load with TOU tariff autonomous 84 EV islanded PSO*

*fig 0.120 winter load with TOU tariff autonomous 84 EV islanded PSO*

**Autonomous 500 EVs:**

For autonomous 500 EVs, when Scheduling strategy-1 is chosen to be the study case for the load to investigate the performance of PSO and ABC algorithms. Table 6 portrays parameters of PSO and proposed ABC algorithms. Looking at the cost in the table below it is shown that the cost is decreased using PSO in all tariffs except CPP. Furthermore, operating cost is high with TOU and CPP and low with RTEP in ABC algorithm. Pollutant emissions are less in ABC with TOU and CPP tariff, and carbon dioxide emissions in case of ABC algorithm are less for RTEP while looking at PSO from table given below IN case of CPP carbon emissions are less whereas equal in both algorithms for TOU tariff.

In case of Scheduling strategy 3 the cost is decreased using ABC in TOU and CPP tariffs for CPP tariff it is decreased in PSO algorithm. Operating cost is also less with TOU and CPP tariffs in ABC algorithm and for RTEP tariff it less in PSO algorithms. Pollutant emissions and carbon dioxide emissions are equal in both algorithms for RTEP tariff, less in ABC for TOU tariff whereas for CPP tariff pollutants emissions are less in PSO and CO2 emissions are less in ABC algorithm.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 1 Grid connected | C1 | 5193.3454 | 5496.6236 | 5146.2741 | 5154.524 | 5254.4618 | 5435.7191 |
| | C2 | 684.9685 | 796.2666 | 793.2547 | 746.8815 | 642.1186 | 888.9239 |
| | C3 | 541.7751 | 495.4318 | 497.3968 | 541.2918 | 511.3589 | 491.4455 |
| | C | 3536.5911 | 3544.4547 | 3549.6747 | 3528.837 | 3566.494 | 3488.8123 |
| 3 Islanded | C1 | 2728.7216 | 2842.5173 | 2761.5445 | 2741.7416 | 2841.4247 | 2789.9975 |
| | C2 | 433.7556 | 544.8264 | 548.4229 | 444.6342 | 544.4423 | 493.3322 |
| | C3 | 181.4753 | 198.2525 | 191.6849 | 183.212 | 198.1319 | 192.4661 |
| | C | 1869.1933 | 1945.656 | 1914.3675 | 1884.5247 | 1944.8457 | 1924.7655 |

*Table 6 Winter load autonomous 544 EV*

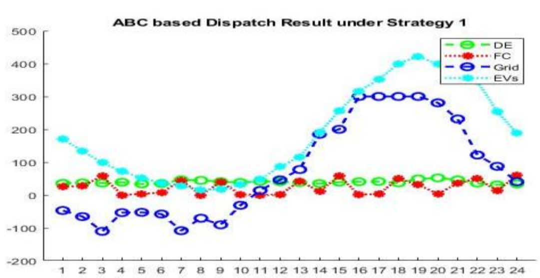



*fig 0.120 winter CPP load with CPP tariff autonomous 544 EV grid connected connected*

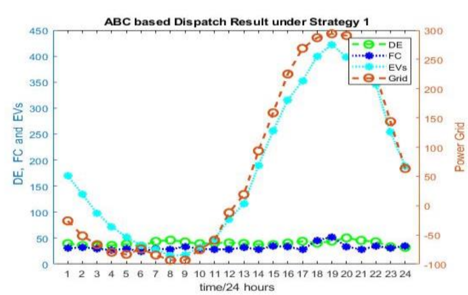



*fig 0.121 winter CPP load with CPP tariff autonomous 544 EV grid*

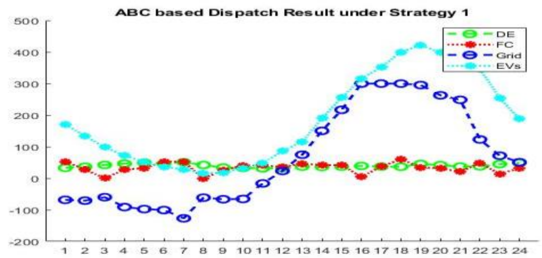
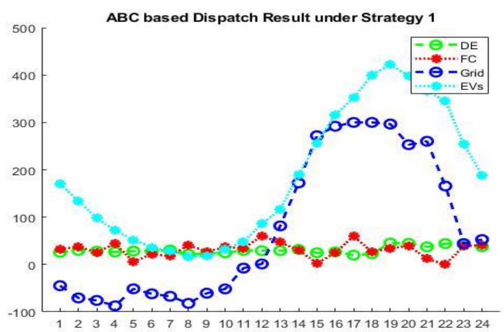




fig 0.122 winter RTEP load with RTEP tariff autonomous 544 EV grid connected
connected

fig 0.123 winter RTEP load with RTEP tariff autonomous 544 EV grid



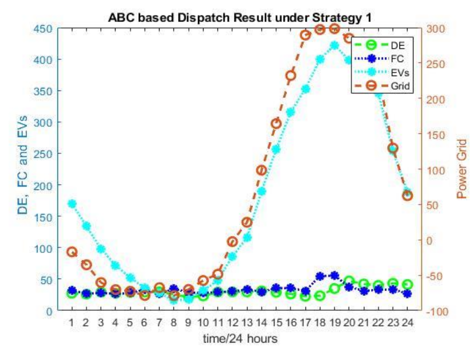
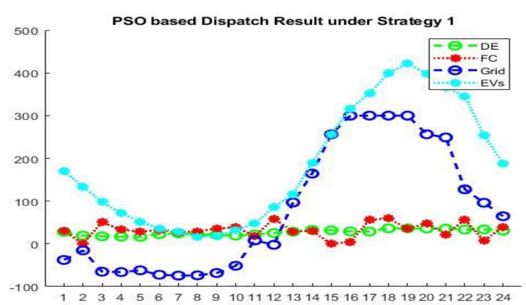




fig 0.124 winter TOU load with TOU tariff autonomous 544 EV grid connected
connected

fig 0.125 winter TOU load with TOU tariff autonomous 544 EV grid



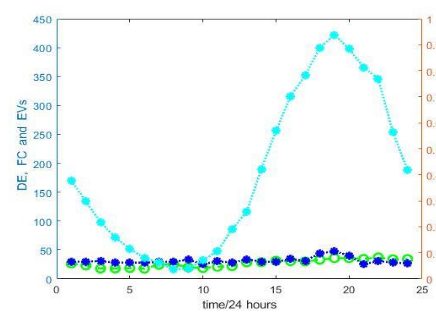




fig 0.126 winter load with CPP tariff autonomous 544 EV grid connected PSO
PSO

fig 0.127 winter load with CPP tariff autonomous 544 EV grid connected

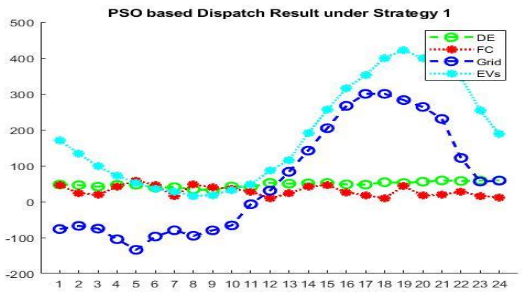



*fig 0.128 winter load with RTEP tariff autonomous 544 EV grid connected PSO PSO*

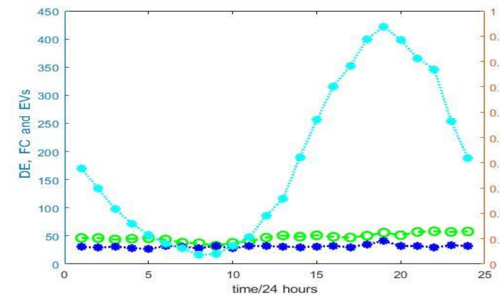



*fig 0.130 winter load with RTEP tariff autonomous 544 EV grid connected*

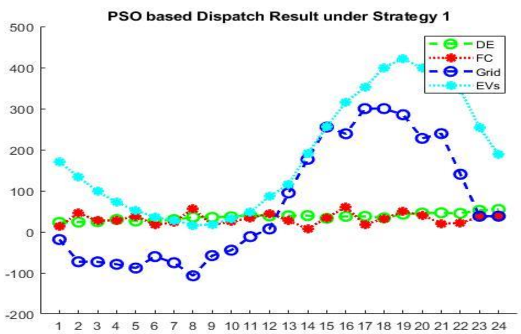



*fig 0.129 winter load with TOU tariff autonomous 544 EV grid connected PSO PSO*

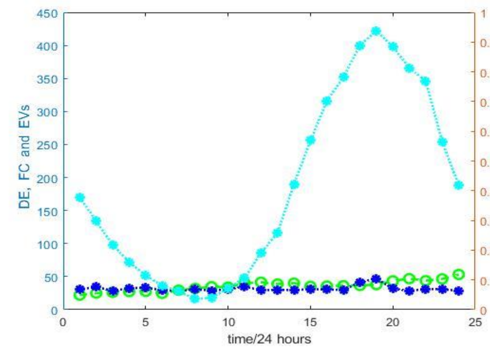



*fig 0.130 winter load with TOU tariff autonomous 544 EV grid connected*

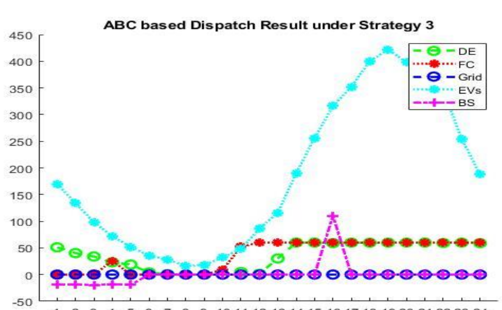



*fig 0.131 winter CPP load with CPP tariff autonomous 544 EV islanded*

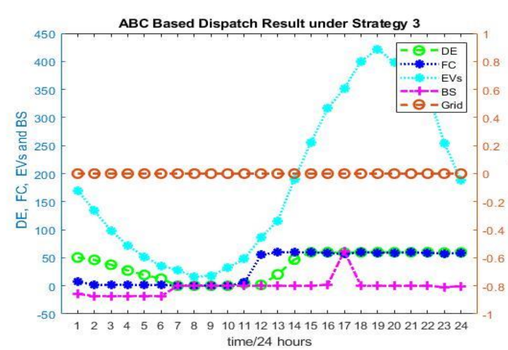



*fig 0.132 winter CPP load with CPP tariff autonomous 544 EV islanded*

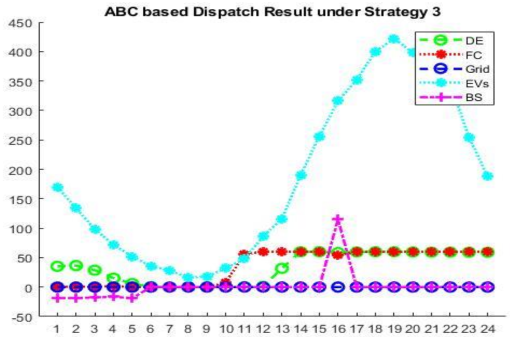



*fig 0.133 winter RTEP load with RTEP tariff autonomous 544 EV islanded*

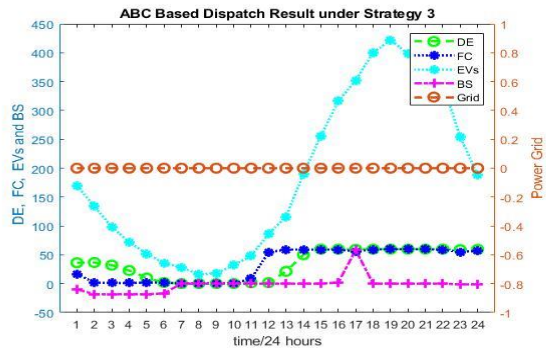



*fig 0.134 winter RTEP load with RTEP tariff autonomous 544 EV islanded*

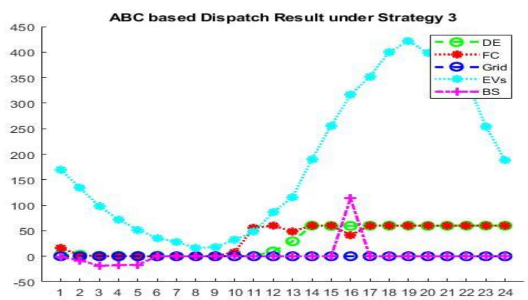



*fig 0.135 winter TOU load with TOU tariff autonomous 544 EV islanded islanded*

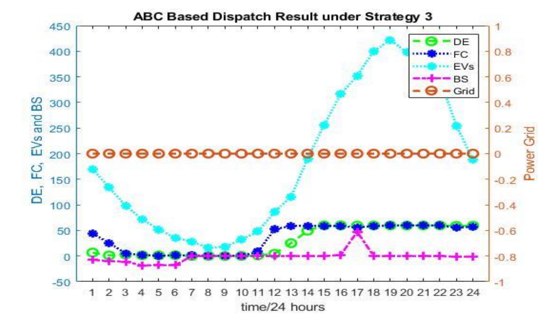



*fig 0.136 winter TOU load with TOU tariff autonomous 544 EV*

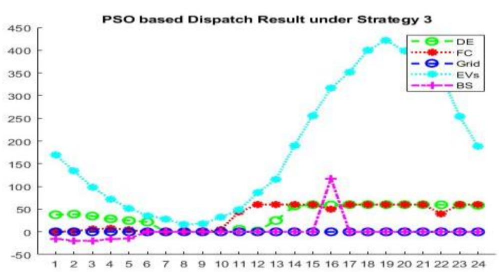



*fig 0.137 winter load with CPP tariff autonomous 544 EV islanded PSO*

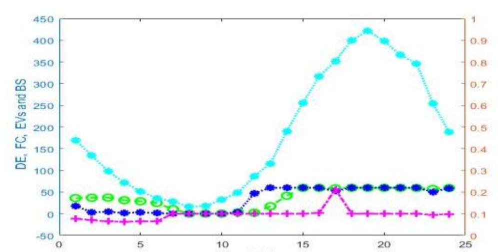



*fig 0.140 winter load with CPP tariff autonomous 544 EV islanded PSO*

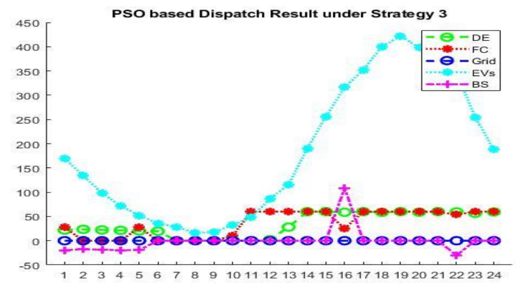



*fig 0.138 winter load with RTEP tariff autonomous 544 EV islanded PSO*

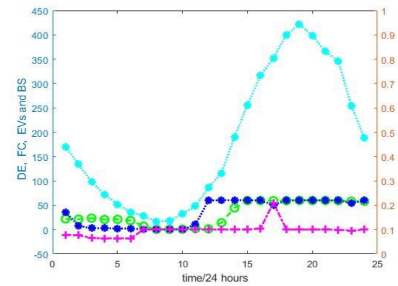



*fig 0.139 winter load with RTEP tariff autonomous 544 EV islanded PS*

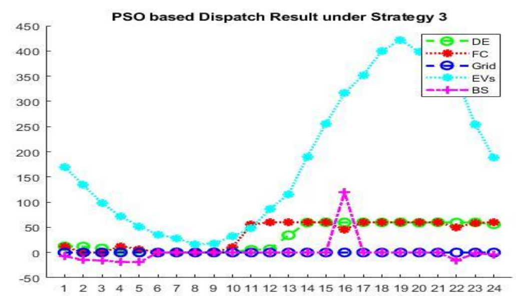



*fig 0.140 winter load with TOU tariff autonomous 544 EV islanded PSO*

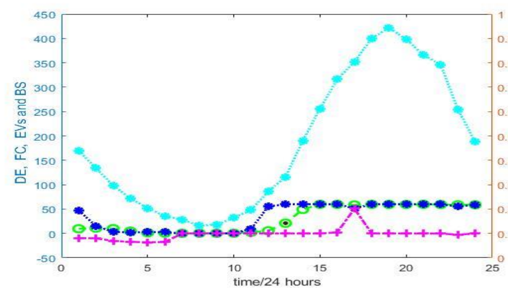



*fig 0.141 winter load with TOU tariff autonomous 544 EV islanded PSO*

**Coordinated 80 EVs:**

For coordinated 80 EVs results are given in table below, when Scheduling strategy-1 is chosen to be the study case for the load to investigate the performance of PSO and ABC algorithms. Table 7 portrays parameters of PSO and proposed ABC algorithms. Looking at the cost in the table below it is shown that the cost is decreased using PSO in all tariffs. When we consider operating cost Pollutant emissions, we can see that both quantities are reduced in PSO algorithm for all tariffs. While carbon dioxide emissions in case of PSO algorithm are less for RTEP tariff, for TOU tariff it reduces in ABC algorithm and when CPP is considered it is equal in both algorithms.

In case of Scheduling strategy 3 the total cost is decreased using ABC in RTEP and CPP tariff whereas for TOU it is less in PSO, the same for operating cost. Pollutant emissions and carbon dioxide emissions in case of ABC algorithm are reduced.

| Scheduling scheme | quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 2 Grid connected | C1 | 1172.7728 | 1193.4256 | 1152.5462 | 1124.5143 | 1464.6449 | 1132.9513 |
| | C2 | 442.3491 | 429.7321 | 382.3793 | 326.9385 | 261.2859 | 327.4822 |
| | C3 | 293.4287 | 298.2494 | 294.7915 | 294.4175 | 288.4786 | 294.3421 |
| | C | 892.437 | 942.4344 | 863.8452 | 831.5475 | 773.2573 | 836.9887 |
| 4 Islanded | C1 | 1535.615 | 1558.4714 | 1522.3632 | 1515.2344 | 1567.7981 | 1557.5249 |
| | C2 | 218.4343 | 175.5562 | 213.3295 | 249.2653 | 184.6911 | 253.9775 |
| | C3 | 72.4682 | 69.3452 | 74.9596 | 74.4632 | 74.9856 | 77.987 |
| | C | 1442.1947 | 1445.3487 | 1432.2778 | 1437.3833 | 1453.8253 | 1465.9485 |

*Table 7 Winter load coordinated 84 EV*

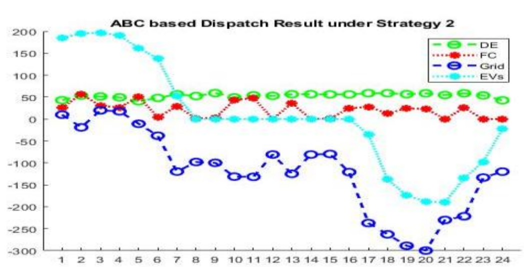



*fig 0.142 winter CPP load with CPP tariff coordinated 84 EV grid connected*

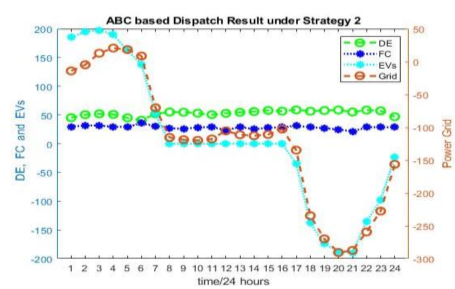
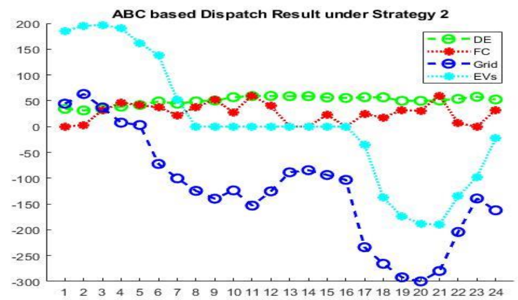



*fig 0.143 winter CPP load with CPP tariff coordinated 84 EV grid connected*



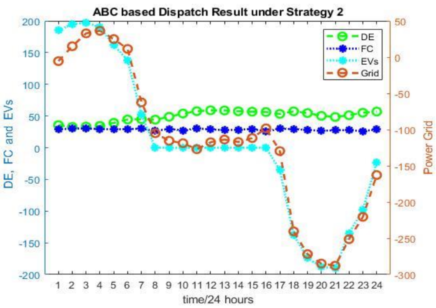
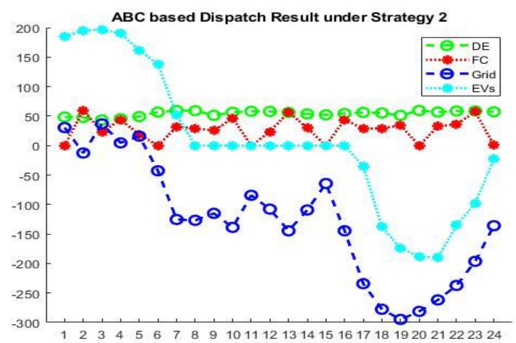




*fig 0.144 winter RTEP load with RTEP tariff coordinated 84 EV grid connected connected*

*fig 0.145 winter RTEP load with RTEP tariff coordinated 84 EV grid*



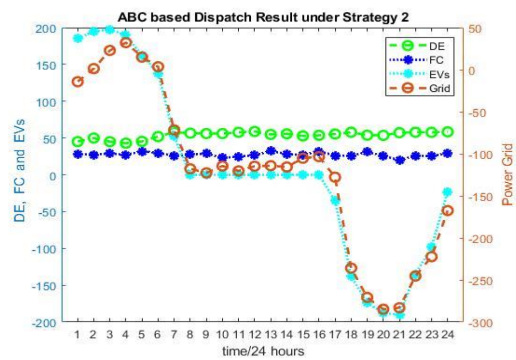
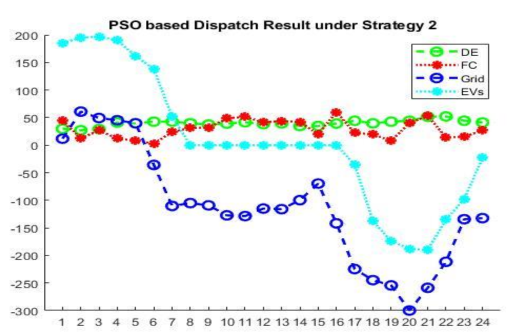




*fig 0.146 winter TOU load with TOU tariff coordinated 84 EV grid connected connected*

*fig 0.150 winter TOU load with TOU tariff coordinated 84 EV grid*



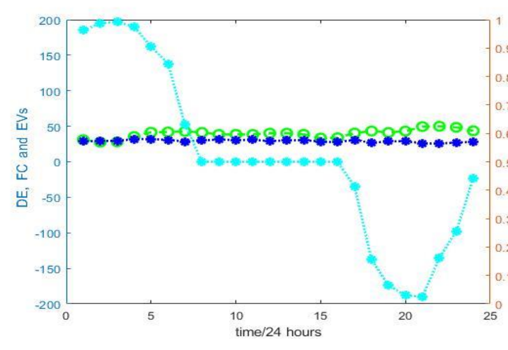
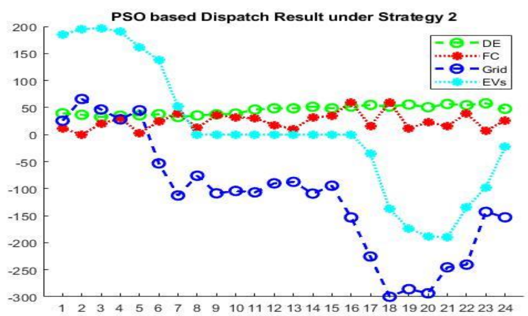



*fig 0.147 winter load with CPP tariff coordinated 84 EV grid connected PSO*

*fig 0.148 winter load with CPP tariff coordinated 84 EV grid connected PSO*



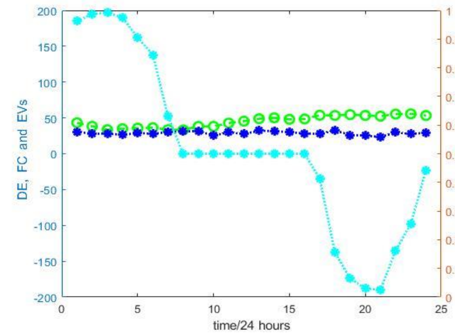
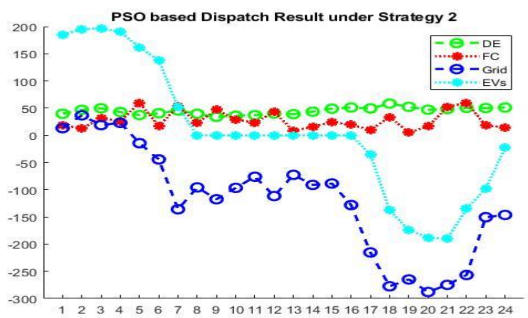




*fig 0.149 winter load with RTEP tariff coordinated 84 EV grid connected PSO PSO*

*fig 0.150 winter load with RTEP tariff coordinated 84 EV grid connected*



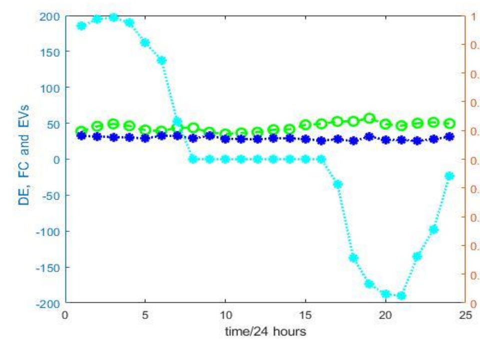
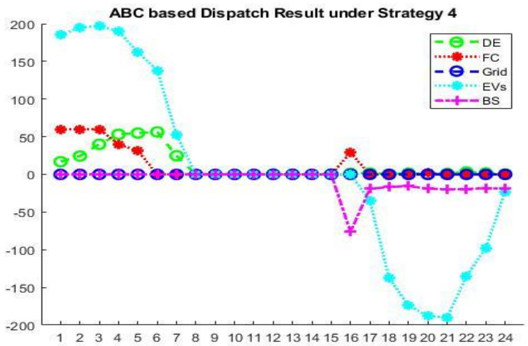




*fig 0.151 winter load with TOU tariff coordinated 84 EV grid connected PSO PSO*

*fig 0.152 winter load with TOU tariff coordinated 84 EV grid connected*



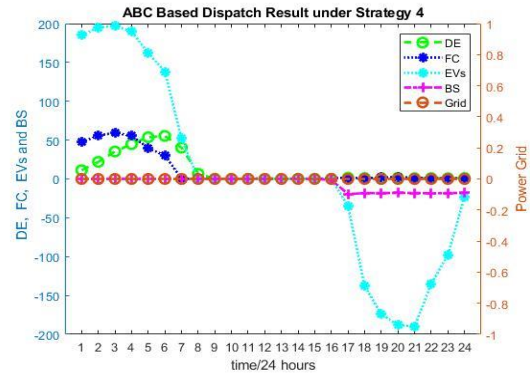
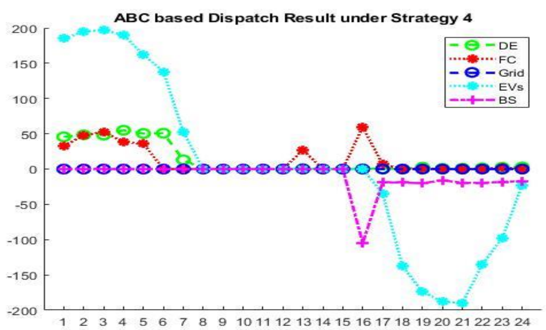




*fig 0.153 winter CPP load with CPP tariff coordinated 84 EV islanded*

*fig 0.154 winter CPP load with CPP tariff coordinated 84 EV islanded*



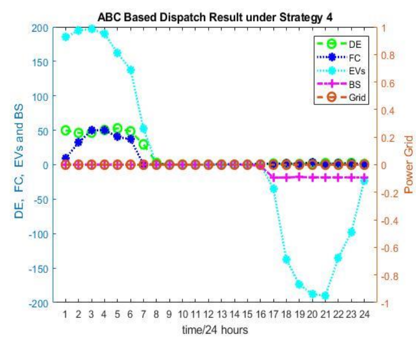
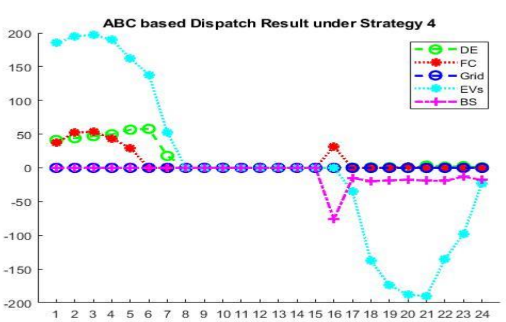




*fig 0.155 winter RTEP load with RTEP tariff coordinated 84 EV islanded*

*fig 0.160 winter RTEP load with RTEP tariff coordinated 84 EV islanded*



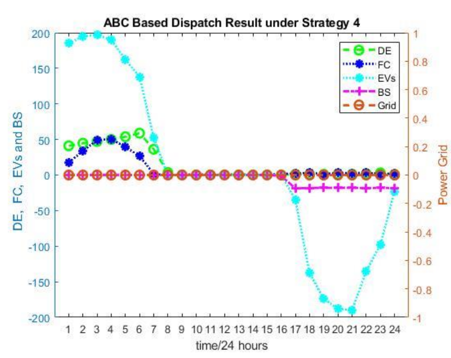
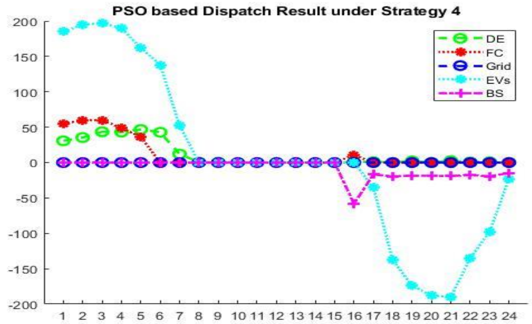




*fig 0.156 winter TOU load with TOU tariff coordinated 84 EV islanded*

*fig 0.157 winter TOU load with TOU tariff coordinated 84 EV islanded*



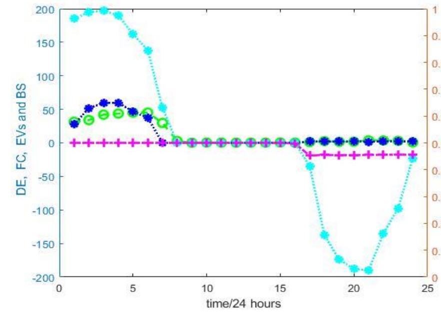
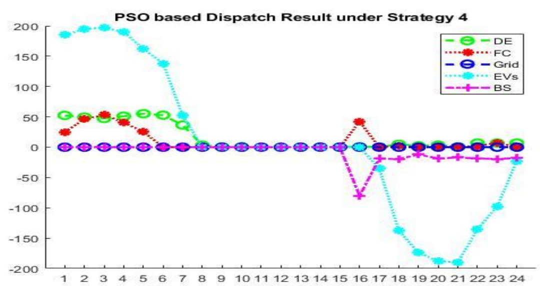




*fig 0.158 winter load with CPP tariff coordinated 84 EV islanded PSO*

*fig 0.159 winter load with CPP tariff coordinated 84 EV islanded PSO*



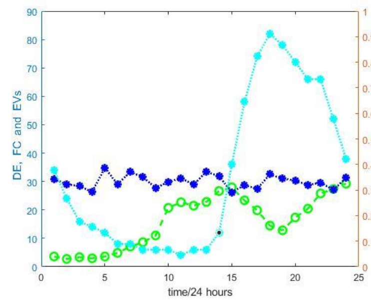
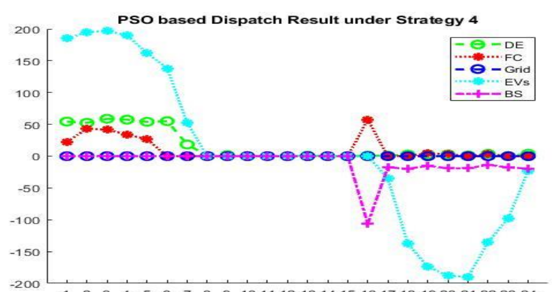




*fig 0.160 winter load with RTEP tariff coordinated 84 EV islanded PSO*

*fig 0.161 winter load with RTEP tariff coordinated 84 EV islanded PSO*



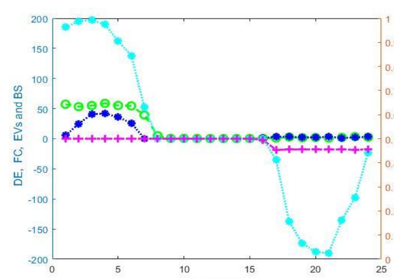




*fig 0.162 winter load with TOU tariff coordinated 84 EV islanded PSO*

*fig 0.163 winter load with TOU tariff coordinated 84 EV islanded PSO*

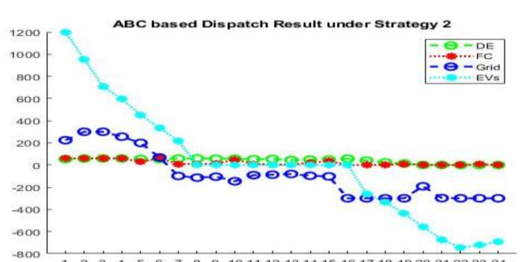
**Coordinated 500 EVs:**

For coordinated 500 EVs, when Scheduling strategy-1 is picked to investigate the performance of PSO and ABC algorithms. Table 8 depicts PSO and proposed ABC algorithms' parameters. Looking at the cost in the table below it is shown that the cost is decreased using ABC in TOU and CPP tariffs whereas looking at RTEP tariff it is decreased in PSO. Moreover, operating cost is less in TOU and RTEP tariffs in PSO algorithm and CPP is low in ABC algorithm. Pollutant emissions and carbon dioxide emissions in case of PSO algorithm are more for all tariffs except RTEP.

In case of Scheduling strategy 2 all the parameters to be considered i.e., total cost, operating cost, pollutants emissions and carbon dioxide emissions are less in ABC algorithm for all three tariffs.

| Scheduling scheme | quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 2 Grid connected | C1 | 374.5678 | 349.3724 | 293.4494 | 366.5313 | 239.9536 | 553.6219 |
| | C2 | 275.4428 | 414.8425 | 392.4745 | 444.5564 | 387.9716 | 538.4755 |
| | C3 | 141.8461 | 144.6723 | 147.2439 | 99.895 | 117.6437 | 73.337 |
| | C | 324.3423 | 315.1729 | 299.143 | 347.4432 | 265.3766 | 499.4238 |
| 4 Islanded | C1 | 1923.8285 | 1924.4857 | 1935.2669 | 1966.4548 | 1977.2194 | 1962.3347 |
| | C2 | 293.574 | 294.1449 | 298.7868 | 318.5441 | 326.4253 | 317.4734 |
| | C3 | 148.3737 | 148.1676 | 149.7662 | 114.1528 | 115.7792 | 113.7253 |
| | C | 1312.6556 | 1314.3871 | 1321.4342 | 1346.6461 | 1355.8232 | 1343.8143 |

*Table 8 Winter load coordinated 544 EV*



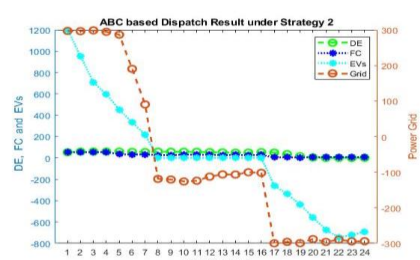
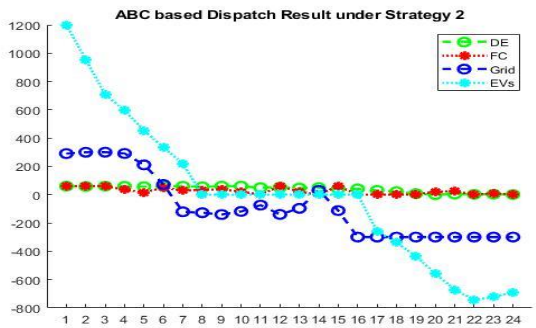



*fig 0.164 winter CPP load with CPP tariff coordinated 544 EV grid connected connected*

*fig 0.170 winter CPP load with CPP tariff coordinated 544 EV grid*



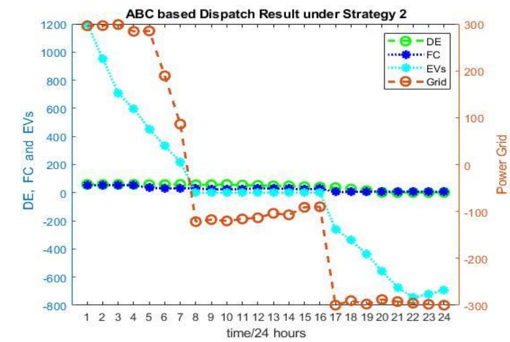
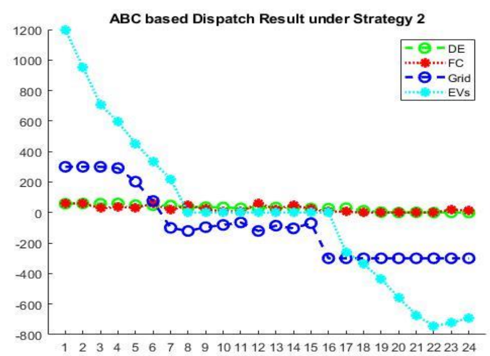




*fig 0.165 winter RTEP load with RTEP tariff coordinated 544 EV grid connected grid connected*

*fig 0.166 winter RTEP load with RTEP tariff coordinated 544 EV*



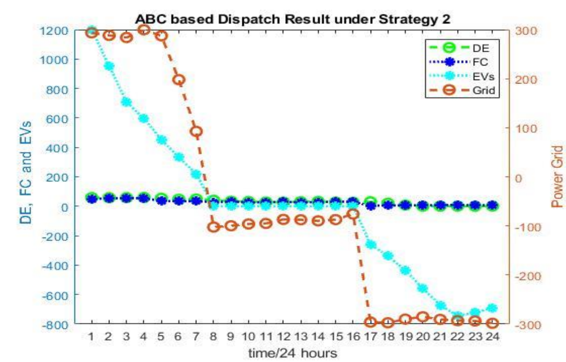
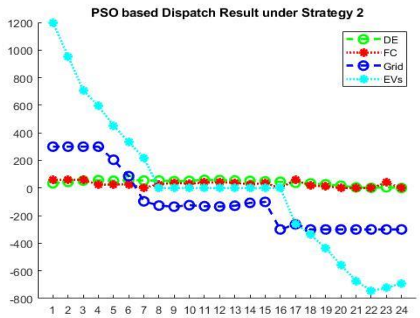




*fig 0.167 winter TOU load with TOU tariff coordinated 544 EV grid connected grid connected*

*fig 0.168 winter TOU load with TOU tariff coordinated 544 EV*



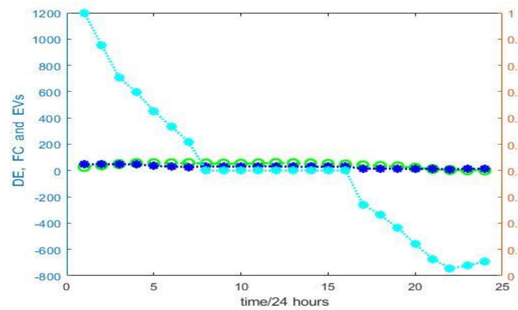
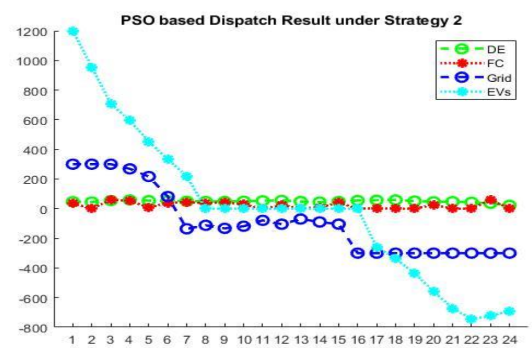




*fig 0.169 winter load with CPP tariff coordinated 544 EV grid connected PSO connected PSO*

*fig 0.170 winter load with CPP tariff coordinated 544 EV grid*



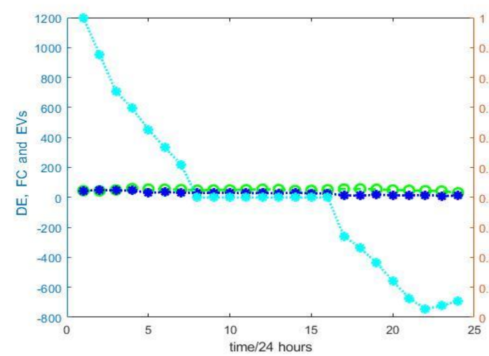
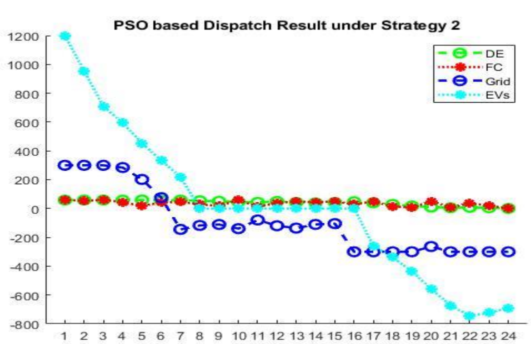




*fig 0.171 winter load with RTEP tariff coordinated 544 EV grid connected PSO connected PSO*

*fig 0.172 winter load with RTEP tariff coordinated 544 EV grid*



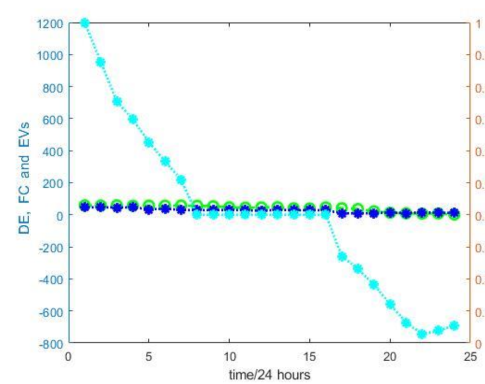



*fig 0.173 winter load with TOU tariff coordinated 544 EV grid connected PSO connected PSO*

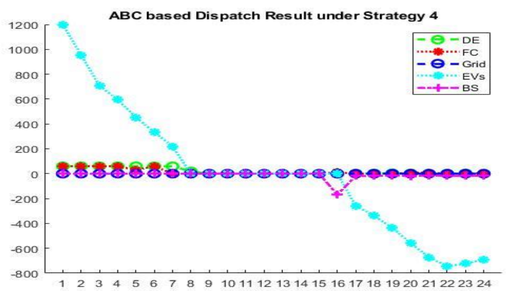



*fig 0.180 winter load with TOU tariff coordinated 544 EV grid*

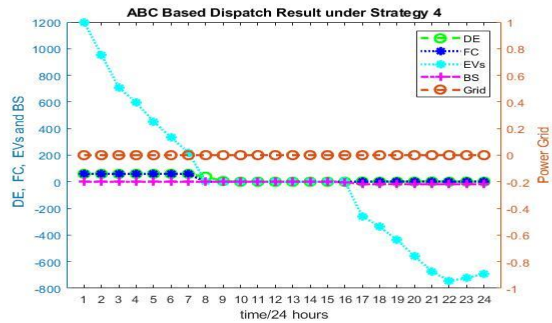



*fig 0.174 winter CPP load with CPP tariff coordinated 544 EV islanded islanded*

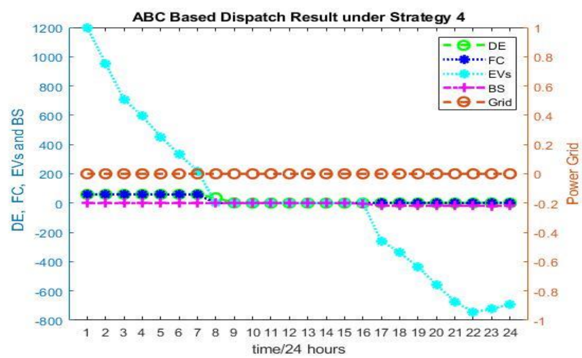



*fig 0.175 winter CPP load with CPP tariff coordinated 544 EV*

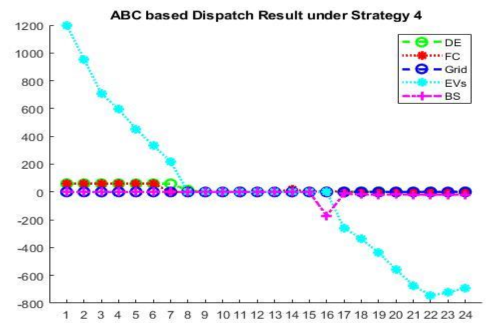



*fig 0.176 winter RTEP load with RTEP tariff coordinated 544 EV islanded islanded*

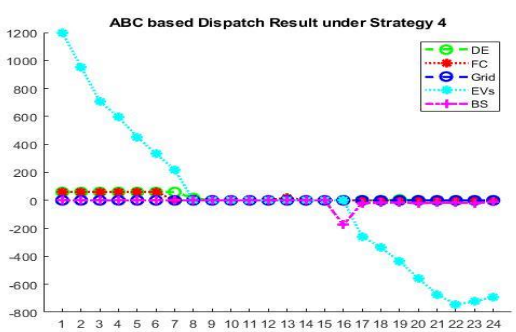



*fig 0.177 winter RTEP load with RTEP tariff coordinated 544 EV*

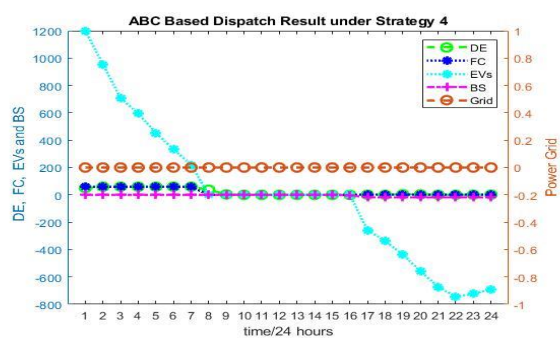
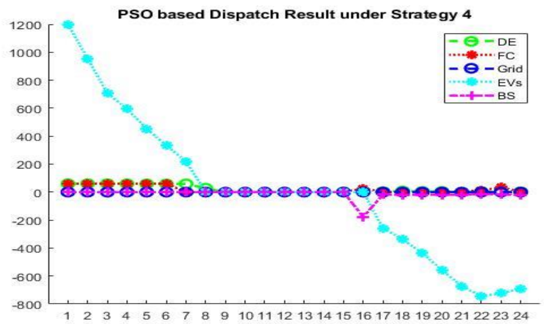


*fig 0.178 winter TOU load with TOU tariff coordinated 544 EV islanded*

*fig 0.179 winter TOU load with TOU tariff coordinated 544 EV islanded*



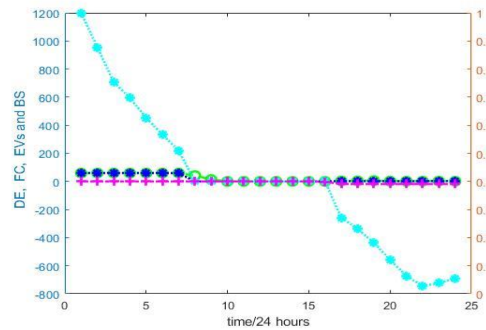
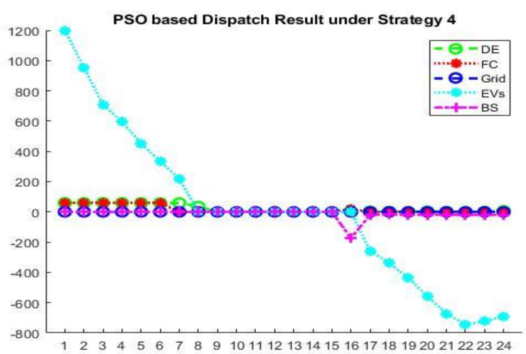




*fig 0.180 winter load with CPP tariff coordinated 544 EV islanded PSO*

*fig 0.181 winter load with CPP tariff coordinated 544 EV islanded PSO*



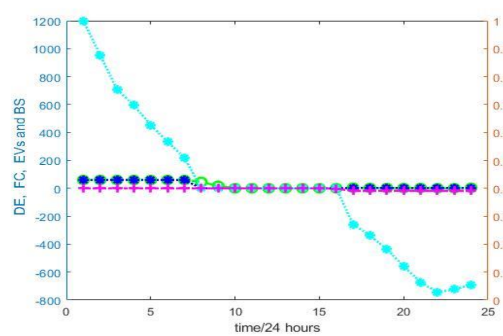
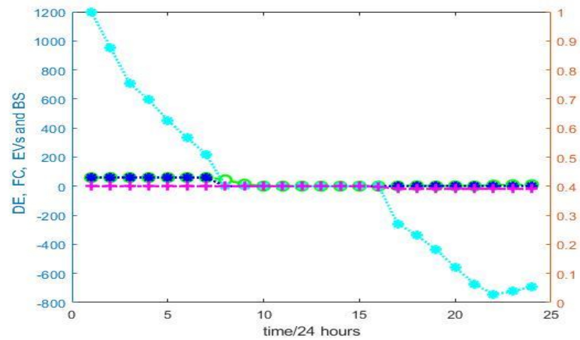




*fig 0.182 winter load with RTEP tariff coordinated 544 EV islanded PSO*

*fig 0.190 winter load with RTEP tariff coordinated 544 EV islanded PSO*



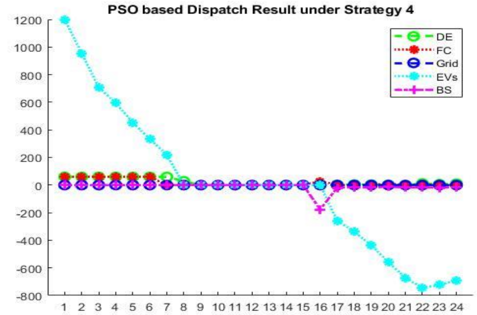




*fig 0.183 winter load with TOU tariff coordinated 544 EV islanded PSO PSO*

*fig 0.184 winter load with TOU tariff coordinated 544 EV islanded*

## Unscheduled summer load:

Summer unscheduled load is taken to examine the performance of PSO and ABC algorithms with three different tariffs i.e., TOU, RTEP and CPP.

### Autonomous 80 EVs:

For autonomous 80 EVs, when scheduling strategy-1 is chosen to be the study case for the unscheduled load to investigate the performance of PSO and ABC algorithms. In the given Table 9 parameters of PSO and proposed ABC algorithms are represented. Looking at the cost in the table below it is shown that that it is decreased using PSO in all tariff's likewise operating cost is also reduced in PSO. Pollutant emissions in case of PSO algorithm for TOU and CPP tariff are less whereas in RTEP tariff it is less in ABC algorithm. Moreover, Carbon dioxide emissions are less for TOU and RTEP in ABC algorithm and for CPP tariff it is less in PSO algorithm.

In case of Scheduling strategy 3 all the parameters i.e., total cost, operating cost, pollutant emissions and CO2 emissions are less in ABC for TOU and CPP tariffs whereas considering RTEP tariff they are less in PSO algorithm.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 1 Grid connected | C1 | 331.492 | 64.1174 | 345.5499 | 299.9142 | 3.1494 | 24.4245 |
| | C2 | 78.4513 | 165.7726 | 544.4449 | 53.2415 | 228.8251 | 257.4646 |
| | C3 | 123.1514 | 154.4437 | 183.4576 | 128.6227 | 156.447 | 164.5995 |
| | C | 244.215 | 99.4133 | 354.3958 | 218.2644 | 77.4917 | 95.9676 |
| 3 Islanded | C1 | 1327.2193 | 1546.181 | 1326.4689 | 1414.9427 | 1355.5444 | 1476.2337 |
| | C2 | 45.6954 | 152.4647 | 42.2873 | 78.4844 | 71.3971 | 137.5928 |
| | C3 | 38.4228 | 62.9773 | 37.961 | 48.4136 | 43.2952 | 59.2396 |
| | C | 861.2647 | 1445.3493 | 859.6432 | 924.4446 | 886.4286 | 982.1435 |

*Table 9 unscheduled summer load autonomous 84 EV*

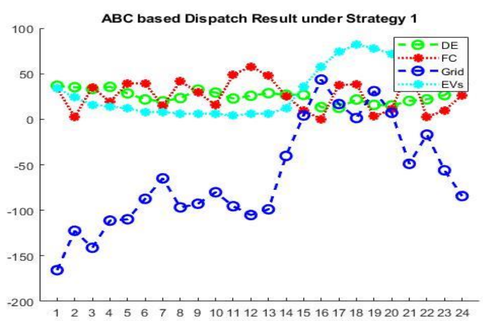



*fig 0.185 autonomous 84 EV grid connected CPP tariff unscheduled load*

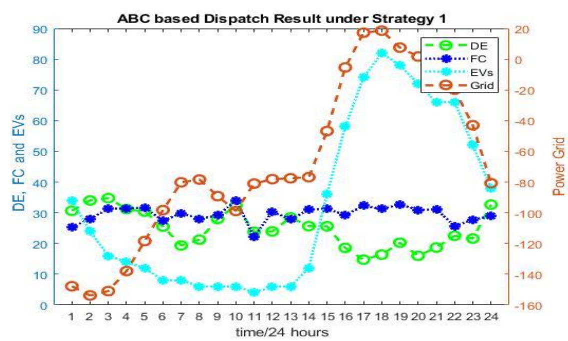



*fig 0.186 autonomous 84 EV grid connected CPP tariff unscheduled load*

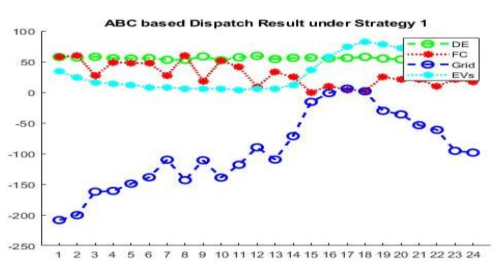



*fig 0.187unscheduled load with RTEP tariff autonomous 84 EV grid connected*

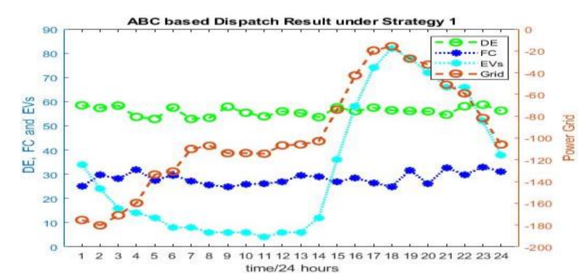
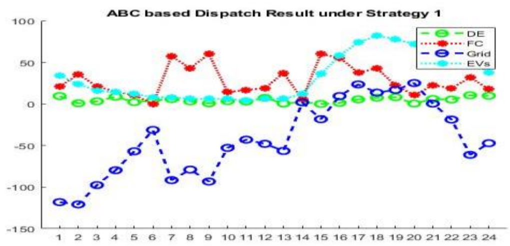



*fig 0.188unscheduled load with RTEP tariff autonomous 84 EV grid connected*



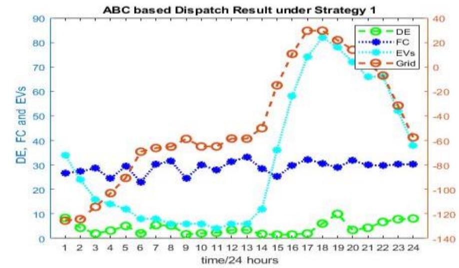
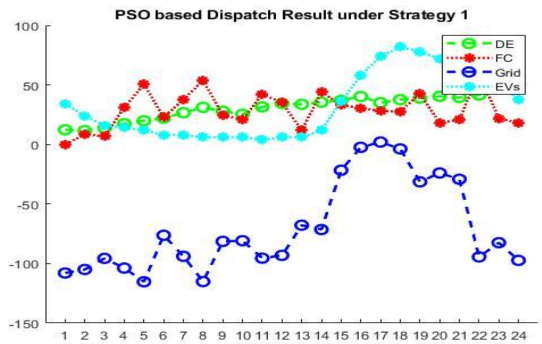




*fig 0.189 unscheduled load with TOU tariff autonomous 84 EV grid connected*
*connected*

*fig 0.190 unscheduled load with TOU tariff autonomous 84 EV grid*



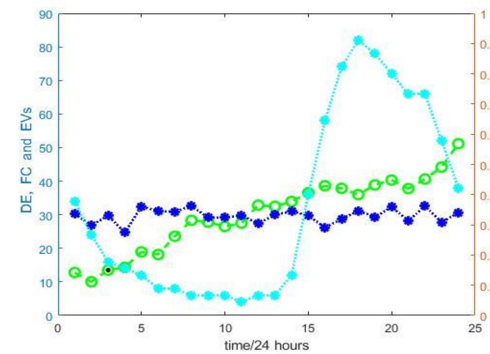
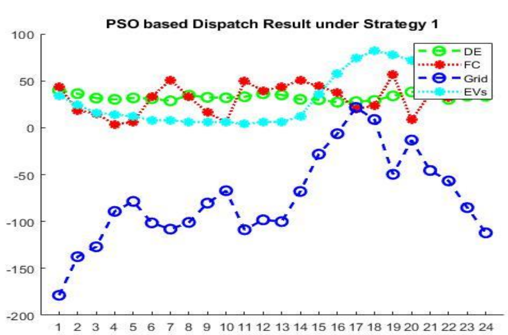




*fig 0.191 summer unscheduled load with CPP tariff autonomous 84 EV grid connected*
*connected*

*fig 0.200 summer unscheduled load with CPP tariff autonomous 84 EV grid*



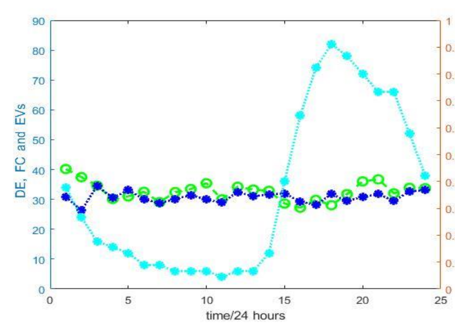
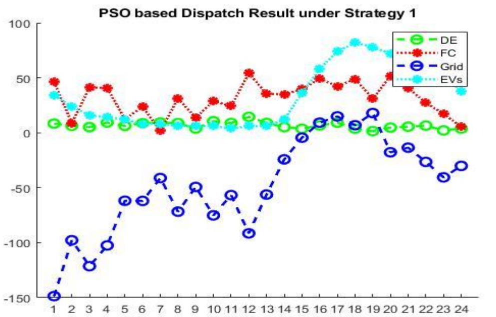




*fig 0.192 summer unscheduled load with RTEP tariff autonomous 84 EV grid connected*
*connected*

*fig 0.193 summer unscheduled load with RTEP tariff autonomous 84 EV grid*



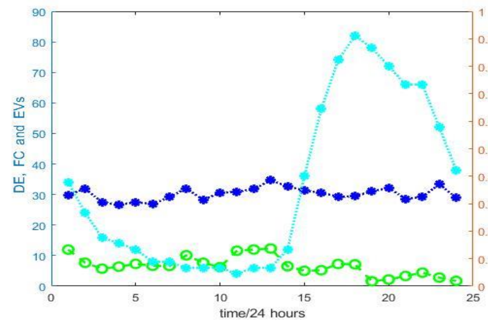
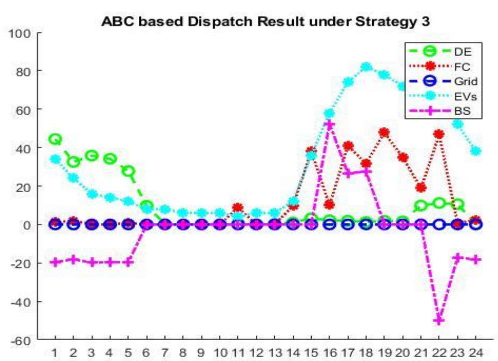




*fig 0.194 summer unscheduled load with TOU tariff autonomous 84 EV grid connected connected*

*fig 0.195 summer unscheduled load with TOU tariff autonomous 84 EV grid*



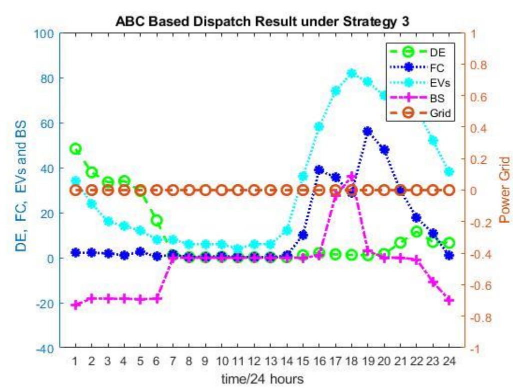
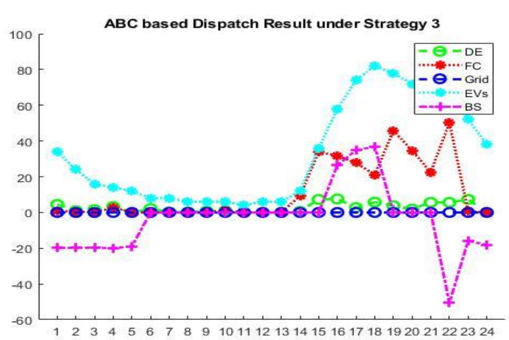




*fig 0.196 autonomous 84 EV islanded CPP tariff unscheduled load*

*fig 0.197 autonomous 84 EV islanded CPP tariff unscheduled load*



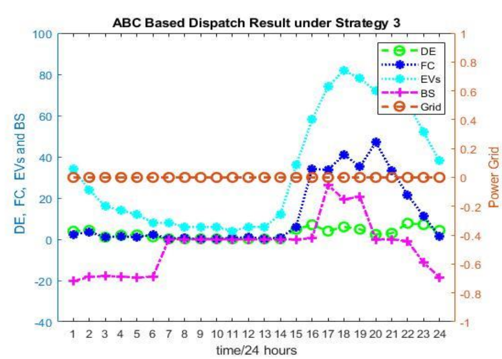



*fig 0.198 unscheduled load with RTEP tariff autonomous 84 EV islanded islanded*

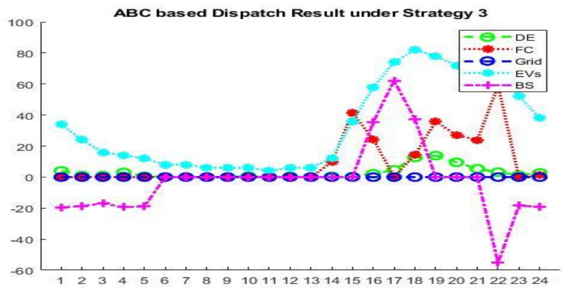



*fig 0.199 unscheduled load with RTEP tariff autonomous 84 EV*

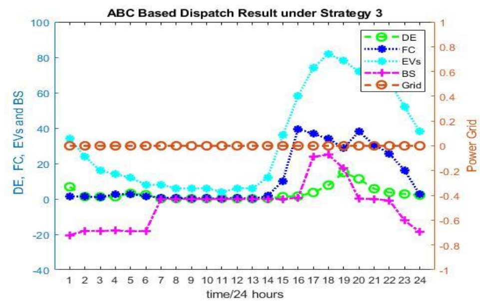



*fig 0.200 unscheduled load with TOU tariff autonomous 84 EV islanded islanded*

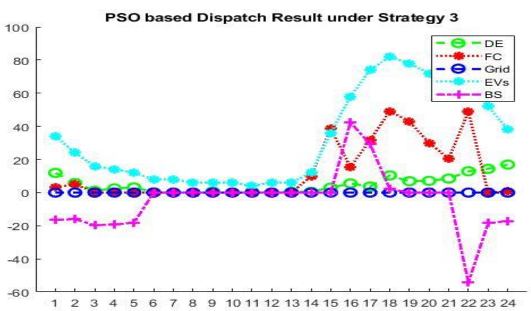



*fig 0.210 unscheduled load with TOU tariff autonomous 84 EV*

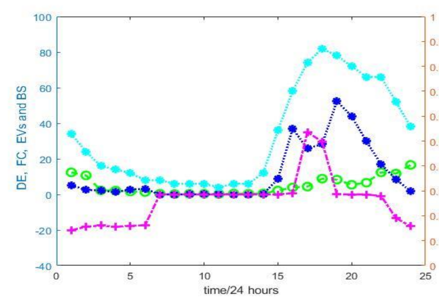



*fig 0.201 summer unscheduled load with CPP tariff autonomous 84 EV islanded PSO islanded PSO*

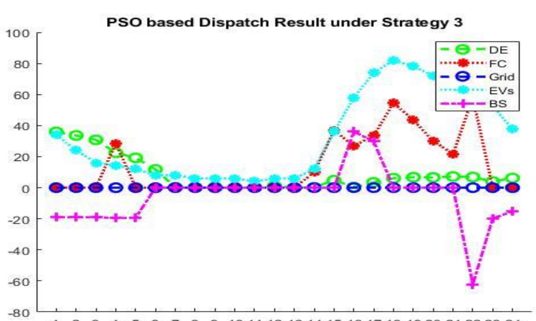



*fig 0.202 summer unscheduled load with CPP tariff autonomous 84 EV*

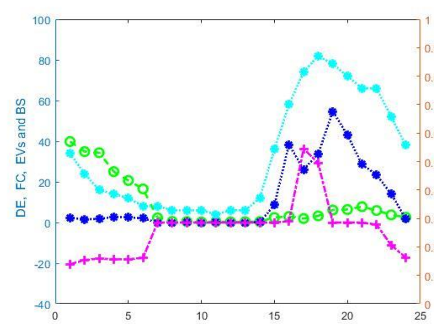
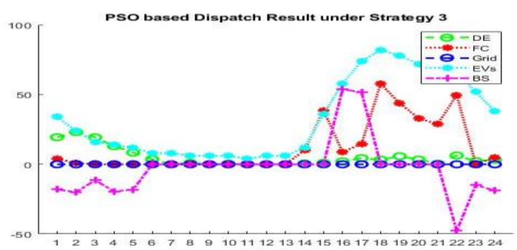


*fig 0.203 summer unscheduled load with RTEP tariff autonomous 84 EV islanded PSO*

*fig 0.204 summer unscheduled load with RTEP tariff autonomous 84 EV islanded PSO*



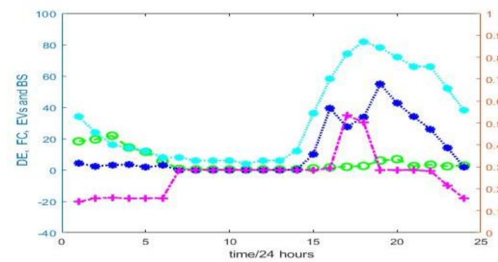




*fig 0.205 summer unscheduled load with TOU tariff autonomous 84 EV islanded PSO*

*fig 0.206 summer unscheduled load with TOU tariff autonomous 84 EV islanded PSO*

**Autonomous 500 EVs:**

Considering autonomous 500 EVs, when Scheduling strategy-1 is chosen to investigate the performance of PSO and ABC algorithms for the unscheduled load. The parameters of PSO and proposed ABC algorithms are displayed in Table 14. Looking at the total cost and operating cost in the table below it is shown that they are decreased using PSO algorithm in TOU and CPP tariffs whereas in RTEP tariff they are decreased using ABC algorithm. Pollutant emissions for TOU and CPP are reduced in ABC algorithm and for RTEP it is reduced in PSO algorithm. For less carbon dioxide emissions PSO is used for TOU and CPP tariffs and ABC is used for RTEPs.

In case of Scheduling strategy 3, all the parameters i.e., total cost, operating cost, pollutant emissions and CO2 emissions are decreased using ABC in RTEP and CPP tariffs and in TOU they are reduced by PSO algorithm.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 1 Grid connected | C1 | 5396.4384 | 5234.552 | 5362.9642 | 5166.3826 | 5441.4454 | 5214.7385 |
| | C2 | 483.2149 | 625.6328 | 477.6317 | 744.774 | 414.5821 | 679.5579 |
| | C3 | 524.9872 | 545.458 | 516.9566 | 542.2747 | 525.4238 | 546.674 |
| | C | 3616.893 | 3546.3422 | 3593.7433 | 3534.9154 | 3627.977 | 3547.819 |
| 3 Islanded | C1 | 2764.7459 | 2741.4796 | 2739.8534 | 2758.3886 | 2881.6453 | 2853.5881 |
| | C2 | 522.8521 | 464.4467 | 483.9358 | 484.8555 | 614.4233 | 581.9468 |
| | C3 | 193.283 | 184.9292 | 187.4629 | 188.8795 | 212.4743 | 246.4563 |
| | C | 1913.8591 | 1884.3631 | 1889.914 | 1942.1474 | 2416.4919 | 1989.6581 |

*Table 10 unscheduled summer load autonomous544 EV*

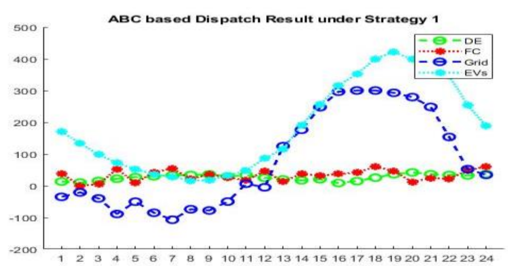



*fig 0.207 autonomous 544 EV grid connected CPP tariff unscheduled load*

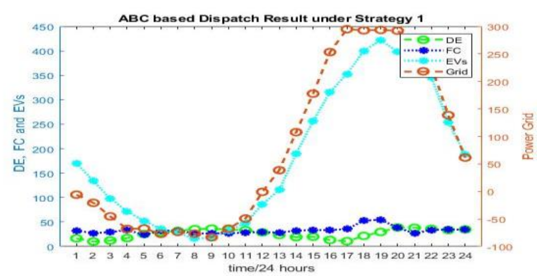
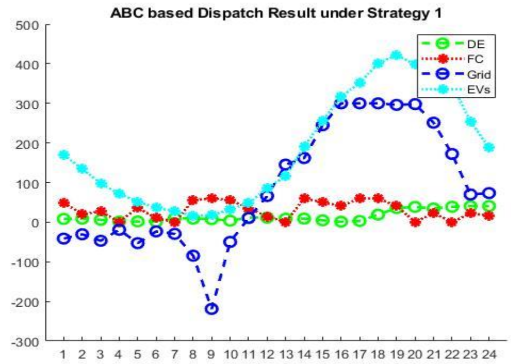



*fig 0.208 autonomous 544 EV grid connected CPP tariff unscheduled load*



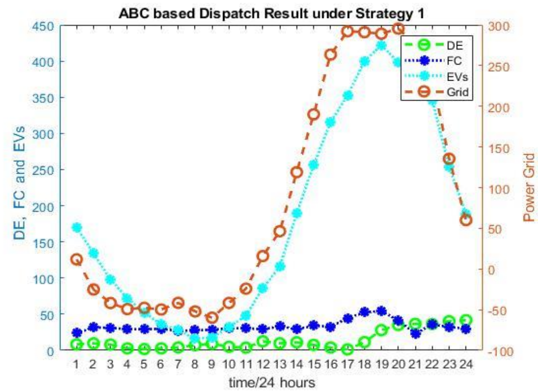
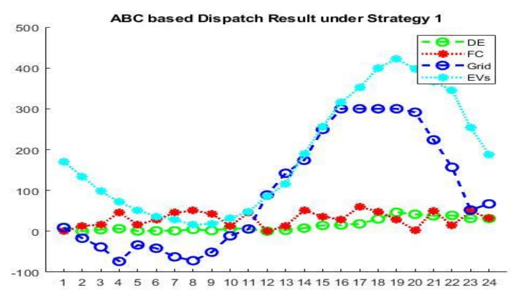




*fig 0.209 unscheduled load with RTEP tariff autonomous 544 EV grid connected connected*

*fig 0.220 unscheduled load with RTEP tariff autonomous 544 EV grid*



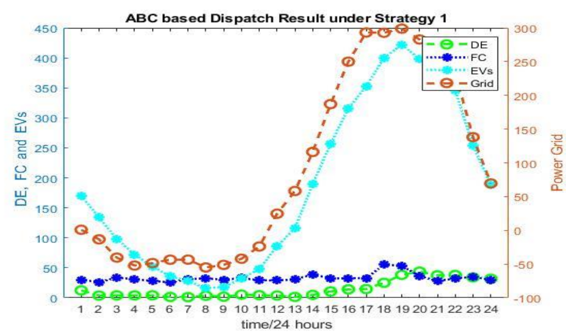
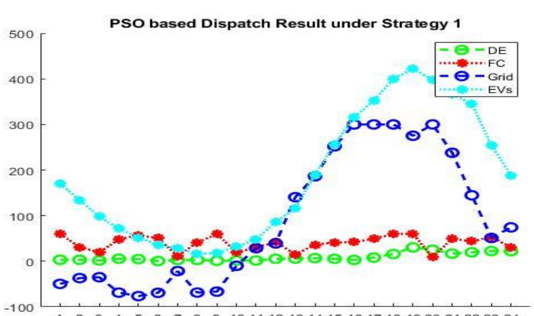




*fig 0.210 unscheduled load with TOU tariff autonomous 544 EV grid connected connected*

*fig 0.211 unscheduled load with TOU tariff autonomous 544 EV grid*



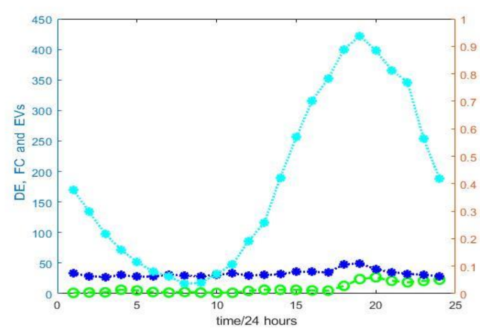
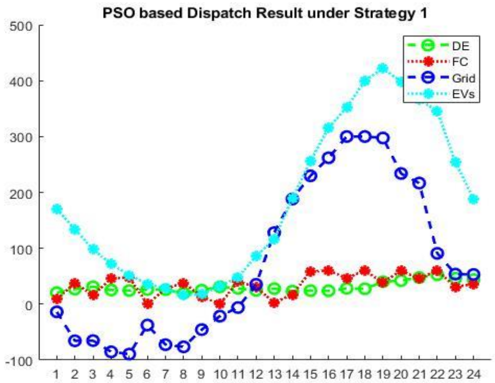




*fig 0.212 summer unscheduled load with CPP tariff autonomous 544 EV grid connected*

*fig 0.213 summer unscheduled load with CPP tariff autonomous 544 EV grid* *connected*



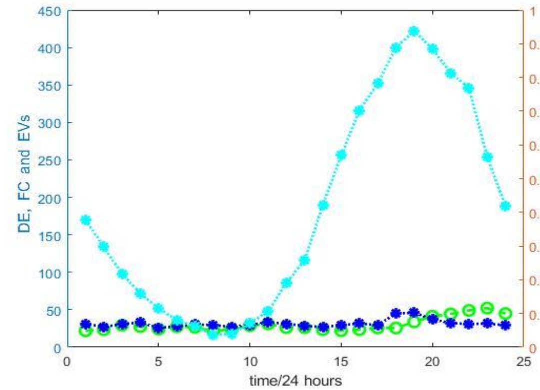
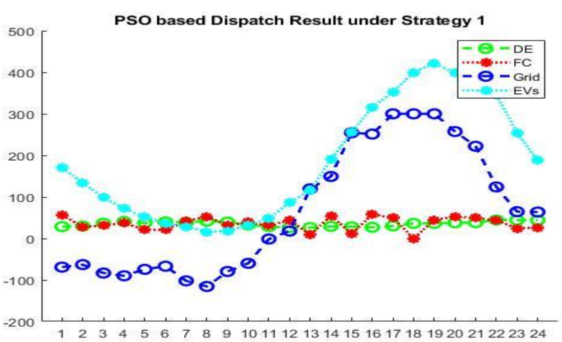




*fig 0.214 summer unscheduled load with RTEP tariff autonomous 544 EV grid connected*
*grid*

*fig 0.215 summer unscheduled load with RTEP tariff autonomous 544 EV*
*connected*



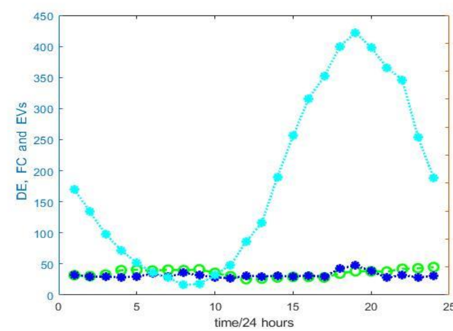
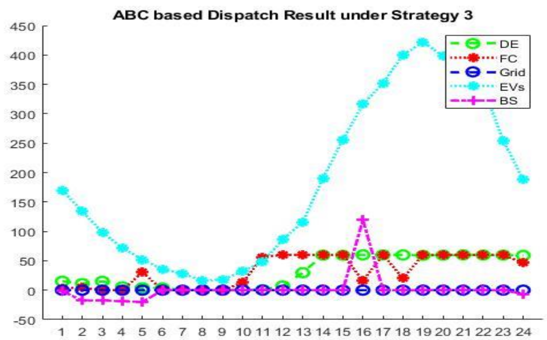




*fig 0.216 summer unscheduled load with TOU tariff autonomous 544 EV grid connected*
*grid connected*

*fig 0.217 summer unscheduled load with TOU tariff autonomous 544 EV*



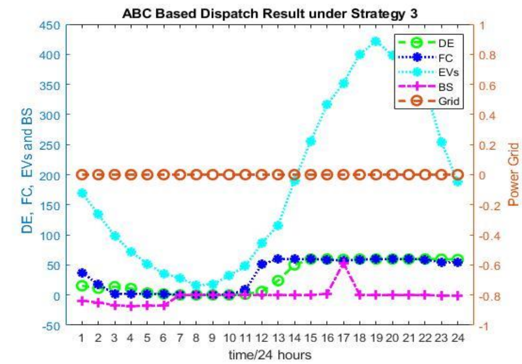
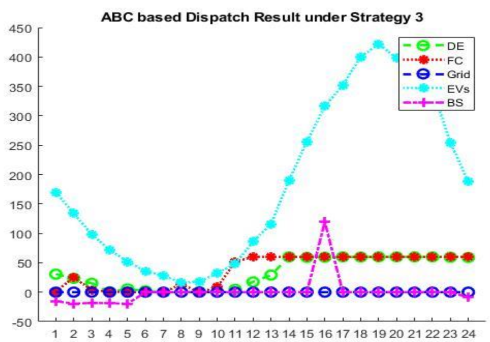




*fig 0.218 autonomous 544 EV islanded CPP tariff unscheduled load*

*fig 0.230 autonomous 544 EV islanded CPP tariff unscheduled load*



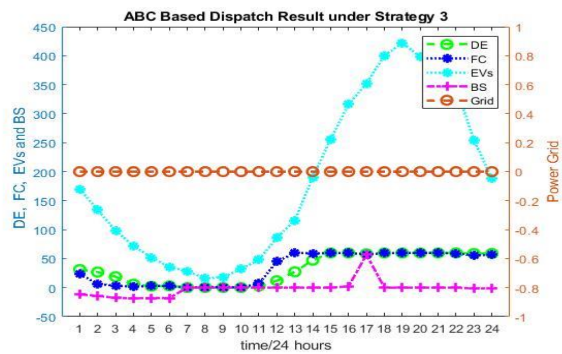
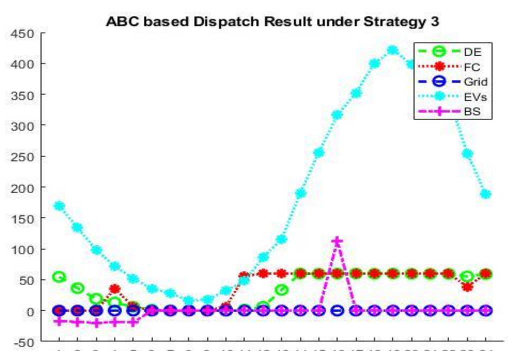




*fig 0.219 unscheduled load with RTEP tariff autonomous 544 EV islanded islanded*

*fig 0.220 unscheduled load with RTEP tariff autonomous 544 EV*



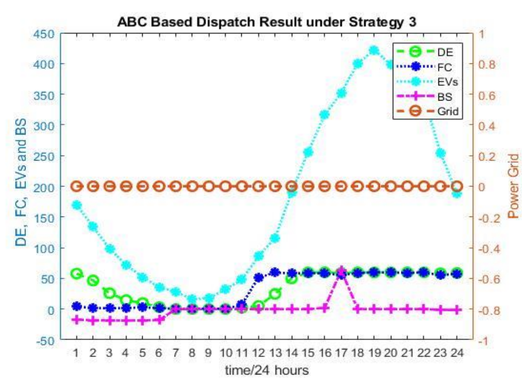



*fig 0.221 unscheduled load with TOU tariff autonomous 544 EV islanded islanded*

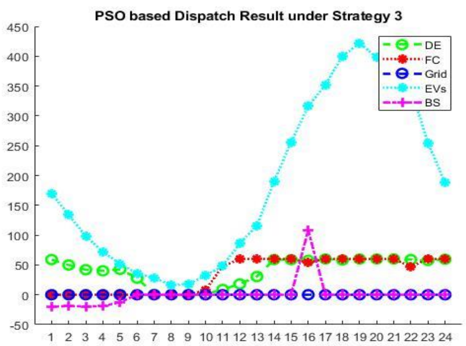



*fig 0.222 unscheduled load with TOU tariff autonomous 544 EV*

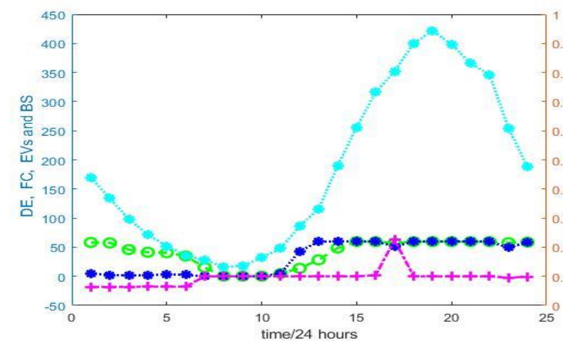



*fig 0.223 summer unscheduled load with CPP tariff autonomous 544 EV islanded PSO islanded PSO*

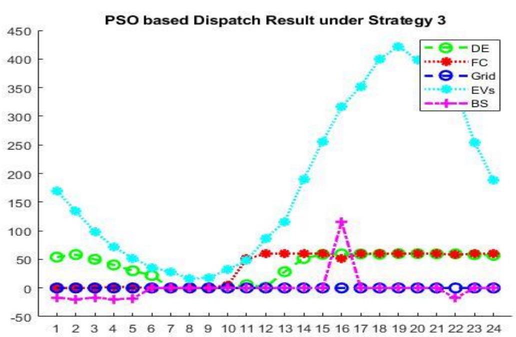



*fig 0.224 summer unscheduled load with CPP tariff autonomous 544 EV*

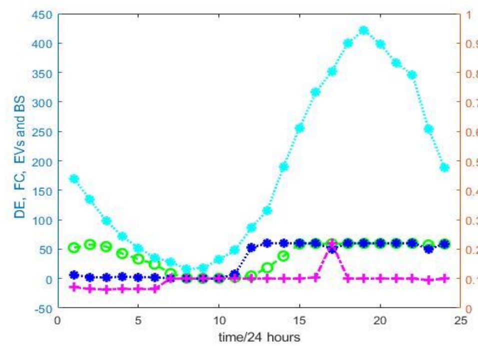



*fig 0.225 summer unscheduled load with RTEP tariff autonomous 544 EV islanded PSO islanded PSO*

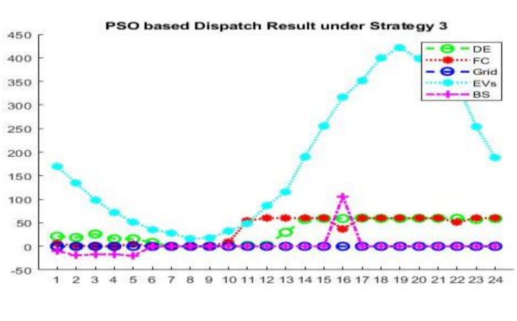



*fig 0.226 summer unscheduled load with RTEP tariff autonomous 544 EV*

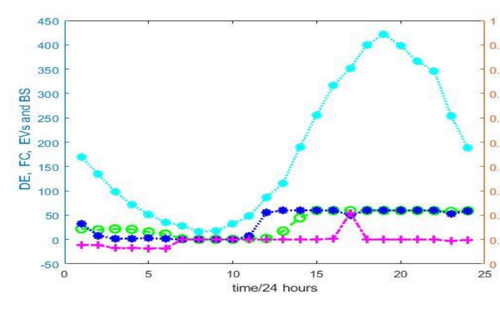


*fig 0.227 summer unscheduled load with TOU tariff autonomous 544 EV islanded PSO* *fig 0.240 summer unscheduled load with TOU tariff autonomous 544 EV islanded PSO*

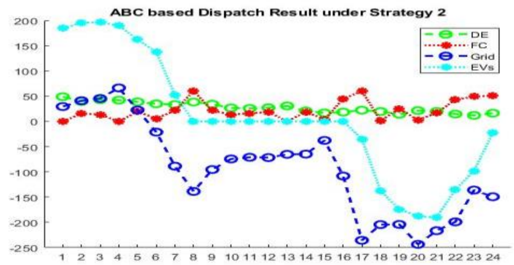
**Coordinated 80 EVs:**

Considering coordinated 80 EVs, when Scheduling strategy-1 is taken to delve into the performance of PSO and ABC algorithms for the unscheduled load. The constraints of PSO and proposed ABC algorithms are presented in Table 11. Looking at the total cost and operating cost in the table below it is shown that all the parameters i.e., total cost, operating cost, pollutant emissions and CO2 emissions are decreased using ABC in CPP tariff and in TOU and RTEP they are reduced by PSO algorithm.

In case of Scheduling strategy 3, the total cost is reduced using ABC algorithm for all tariffs. The table given below tells that operating cost is decreased using ABC algorithm in TOU and RTEP tariffs whereas in CPP tariff it is decreased by using PSO algorithm. Pollutant emissions for TOU and RTEP are reduced in PSO algorithm and for CPP it is reduced in ABC algorithm. For less carbon dioxide emissions PSO is used in TOU, and ABC is used in CPP.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 2 Grid connected | C1 | 1432.5258 | 899.1437 | 963.4248 | 847.4898 | 724.6747 | 1114.8881 |
| | C2 | 271.2627 | 123.4665 | 184.2954 | 53.7243 | 78.4864 | 348.4813 |
| | C3 | 282.3345 | 271.4364 | 278.9393 | 267.8188 | 256.6923 | 292.6667 |
| | C | 757.3465 | 632.9241 | 694.51 | 581.7676 | 546.1152 | 817.8553 |
| 4 Islanded | C1 | 1514.1148 | 1554.3976 | 1566.5852 | 1549.9354 | 1571.7893 | 1564.8378 |
| | C2 | 229.618 | 161.7697 | 141.1942 | 191.4988 | 147.4455 | 161.8328 |
| | C3 | 71.9483 | 67.1947 | 66.4468 | 74.4787 | 67.1132 | 67.9419 |
| | C | 1428.7797 | 1436.4237 | 1441.3443 | 1444.1521 | 1446.3417 | 1443.1686 |

*Table 11 Unscheduled Summer load coordinated 84EV*



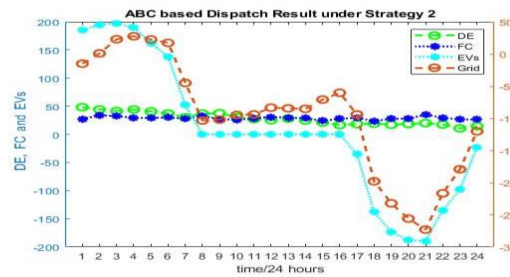
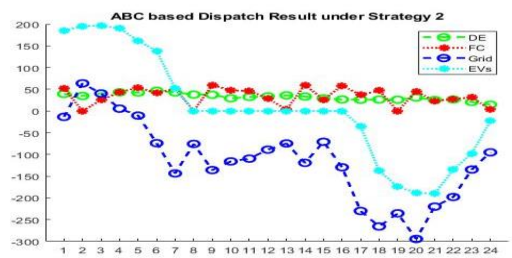




*fig 0.228 coordinated 84 EV grid connected CPP tariff unscheduled load*
*load*

*fig 0.229 coordinated 84 EV grid connected CPP tariff unscheduled*



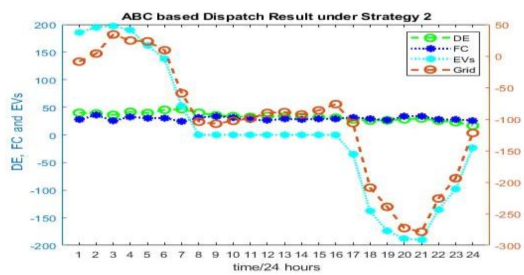
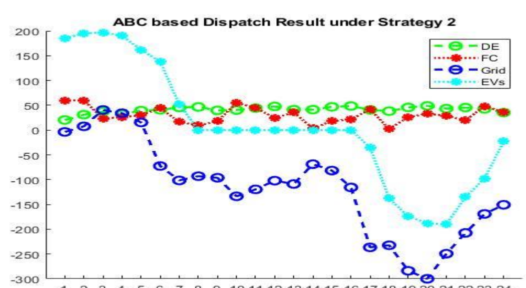




*fig 0.230 unscheduled load with RTEP tariff coordinated 84 EV grid connected*
*connected*

*fig 0.231 unscheduled load with RTEP tariff coordinated 84 EV grid*



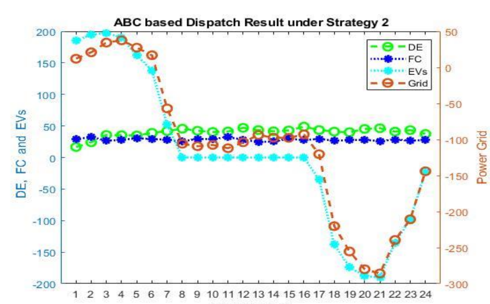
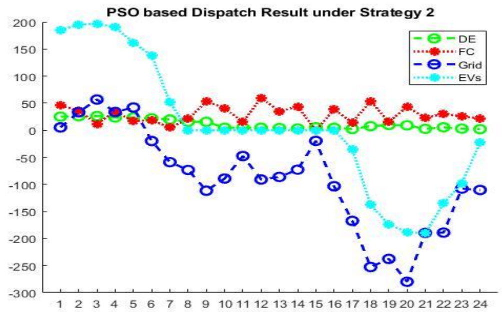




*fig 0.232 unscheduled load with TOU tariff coordinated 84 EV grid connected*
*connected*

*fig 0.233 unscheduled load with TOU tariff coordinated 84 EV grid*



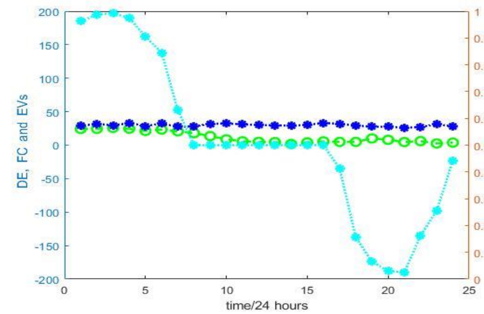
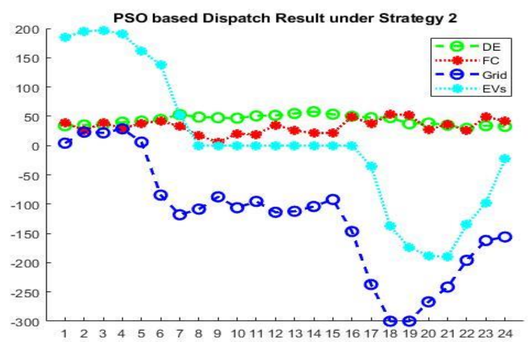




*fig 0.234 summer unscheduled load with CPP tariff coordinated 84 EV grid connected*
*connected*

*fig 0.235 summer unscheduled load with CPP tariff coordinated 84 EV grid*



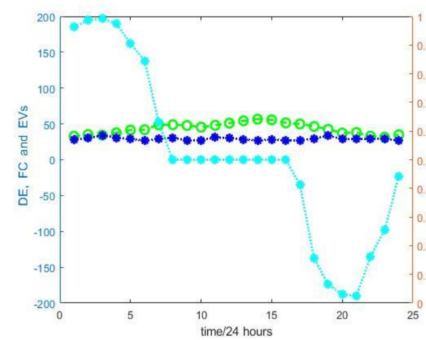
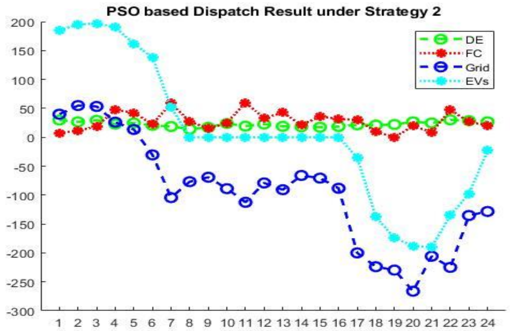




*fig 0.236 summer unscheduled load with RTEP tariff coordinated 84 EV grid connected*
*grid connected*

*fig 0.250 summer unscheduled load with RTEP tariff coordinated 84 EV*



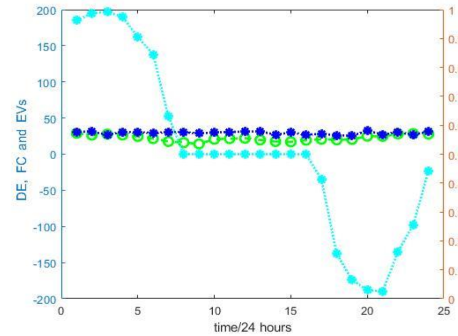
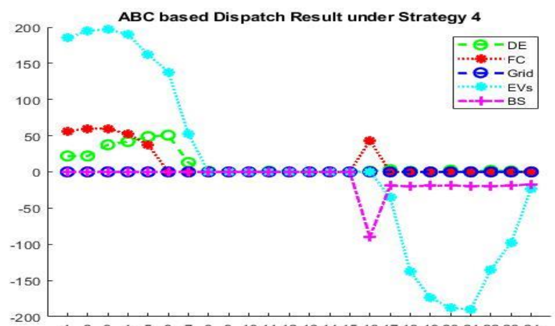




*fig 0.237 summer unscheduled load with TOU tariff coordinated 84 EV grid connected grid connected*

*fig 0.238 summer unscheduled load with TOU tariff coordinated 84 EV*



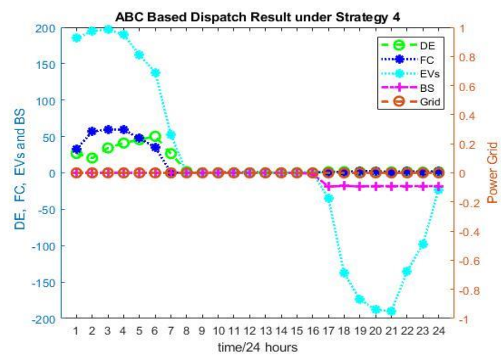
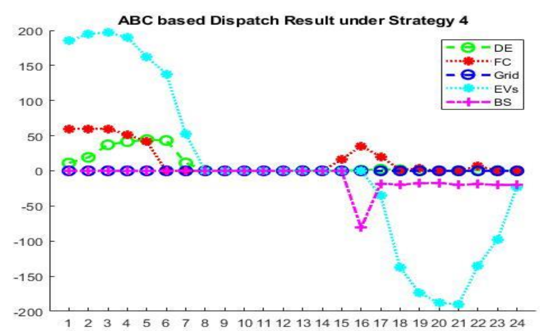




*fig 0.239 coordinated 84 EV islanded CPP tariff unscheduled load load*

*fig 0.240 coordinated 84 EV islanded CPP tariff unscheduled*



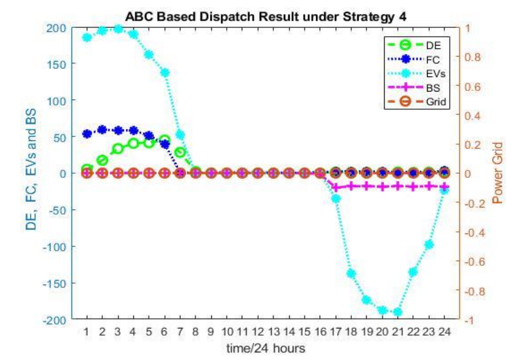
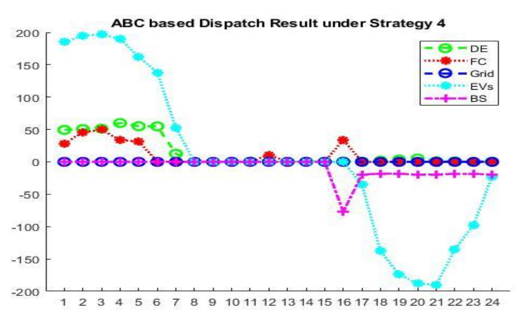




*fig 0.241 unscheduled load with RTEP tariff coordinated 84 EV islanded islanded*

*fig 0.242 unscheduled load with RTEP tariff coordinated 84 EV*



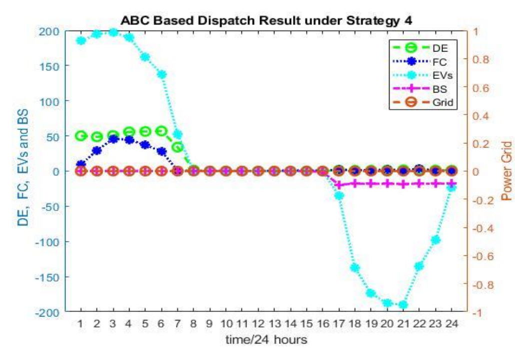
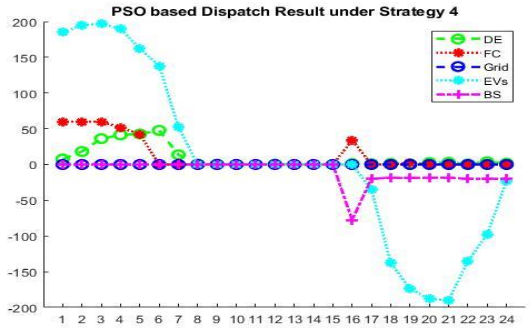




*fig 0.243 unscheduled load with TOU tariff coordinated 84 EV islanded islanded*

*fig 0.244 unscheduled load with TOU tariff coordinated 84 EV*



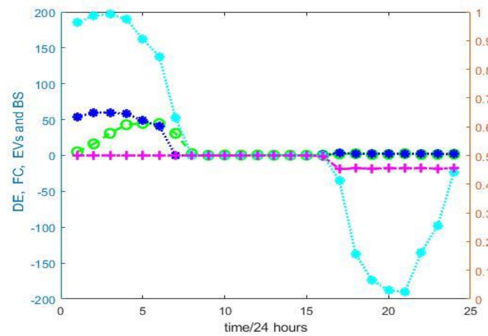
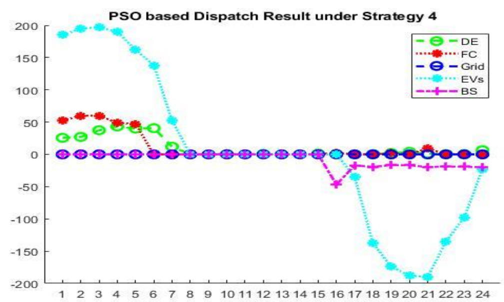




*fig 0.245 summer unscheduled load with CPP tariff coordinated 84 EV islanded PSO islanded PSO*

*fig 0.260 summer unscheduled load with CPP tariff coordinated 84 EV*



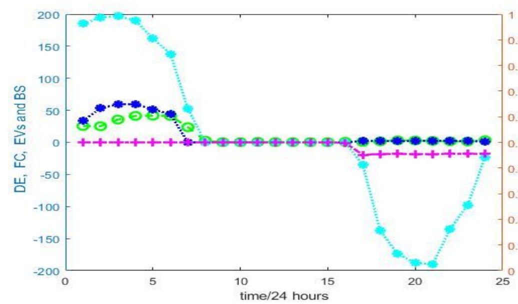
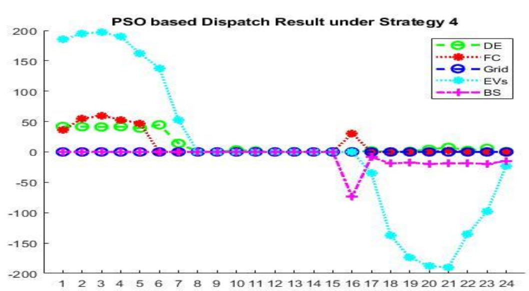




*fig 0.246 summer unscheduled load with RTEP tariff coordinated 84 EV islanded PSO islanded PSO*

*fig 0.247 summer unscheduled load with RTEP tariff coordinated 84 EV*



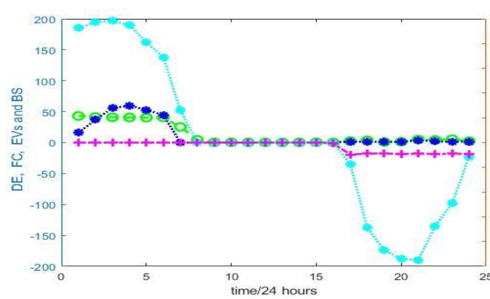




*fig 0.248 summer unscheduled load with TOU tariff coordinated 84 EV islanded PSO islanded PSO*

*fig 0.249 summer unscheduled load with TOU tariff coordinated 84 EV*

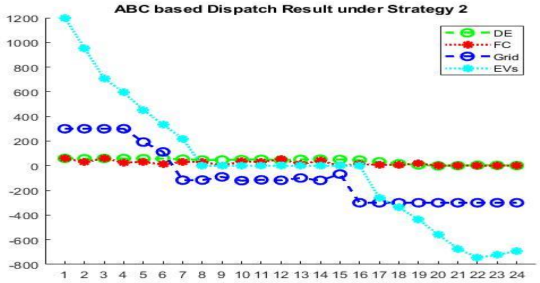
**Coordinated 500 EVs:**

Considering coordinated 500 EVs, when Scheduling strategy-1 is chosen to delve into the performance of PSO and ABC algorithms for the unscheduled load. The parameters of PSO and proposed ABC algorithms are displayed in Table 12. Looking at the table below it is shown that total cost, operating cost, and pollutant emissions are decreased using ABC algorithm in TOU and CPP tariffs, whereas in RTEP tariff they are decreased using PSO algorithm. For less carbon dioxide emissions PSO is used for TOU and CPP tariffs and ABC is used for RTEPs.

In case of Scheduling strategy 3, all the parameters i.e., total cost, operating cost, pollutant emissions and CO2 emissions are decreased using ABC in all tariffs.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 2 Grid connected | C1 | 311.8242 | 348.9456 | 355.4896 | 415.2414 | 245.4224 | 416.3875 |
| | C2 | 447.2342 | 384.9995 | 348.495 | 496.7144 | 121.9186 | 472.6143 |
| | C3 | 145.2469 | 148.2482 | 141.643 | 91.9448 | 126.3657 | 92.5843 |
| | C | 314.8375 | 346.5441 | 316.6656 | 442.4456 | 244.8413 | 397.4487 |
| 4 Islanded | C1 | 1924.9259 | 1941.472 | 1926.5171 | 1963.5318 | 1979.6736 | 1955.438 |
| | C2 | 293.2773 | 344.4372 | 297.4653 | 314.6731 | 322.4556 | 314.5158 |
| | C3 | 41 | 114.3172 | 148.9538 | 113.5424 | 115.555 | 112.5447 |
| | C | 1313.2827 | 1325.5127 | 1315.3348 | 1343.9377 | 1356.441 | 1337.5995 |

*Table 12 Unscheduled Summer load with coordinated 544 EV*



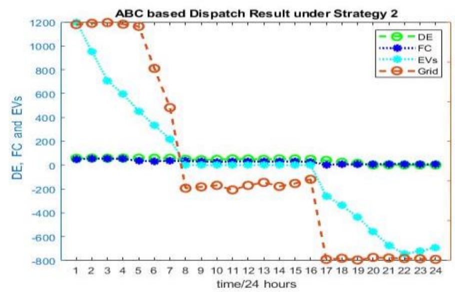
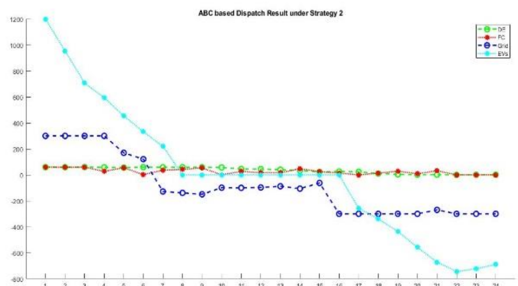




*fig 0.250 coordinated 544 EV grid connected CPP tariff unscheduled load load*

*fig 0.251 coordinated 544 EV grid connected CPP tariff unscheduled*



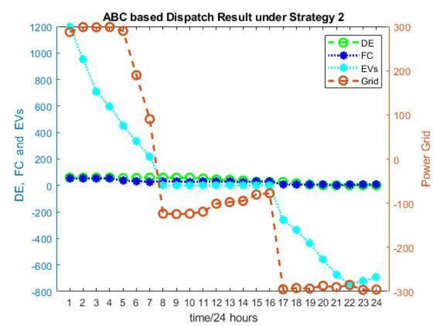
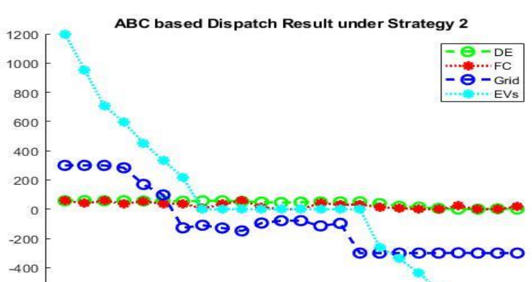



*fig 0.252 unscheduled load with RTEP tariff coordinated 544 EV grid connected connected*

*fig 0.253 unscheduled load with RTEP tariff coordinated 544 EV grid*



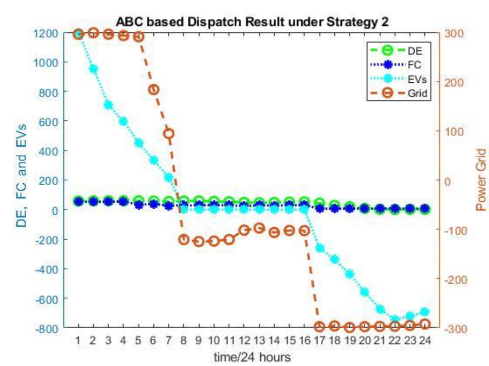
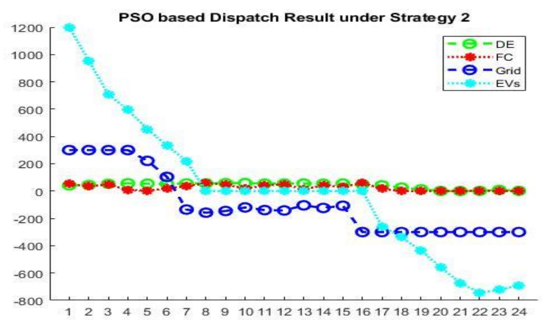



*fig 0.254 unscheduled load with TOU tariff coordinated 544 EV grid connected grid connected*

*fig 0.270 unscheduled load with TOU tariff coordinated 544 EV*



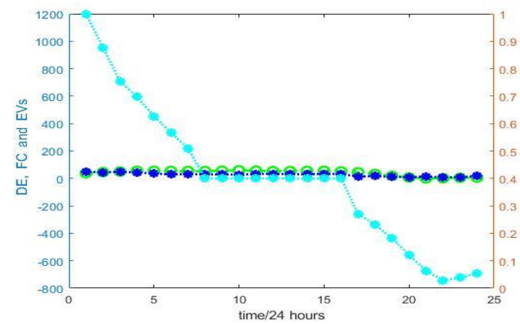
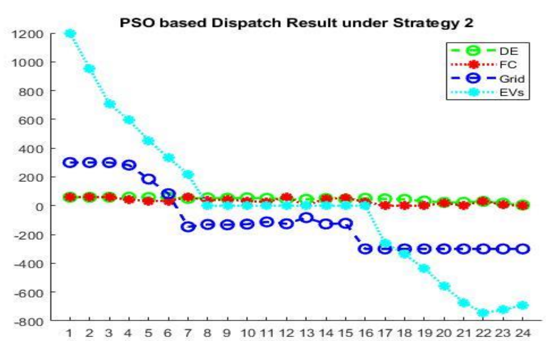




*fig 0.255 summer load with CPP tariff coordinated 544 EV grid connected PSO connected PSO*

*fig 0.256 summer load with CPP tariff coordinated 544 EV grid*



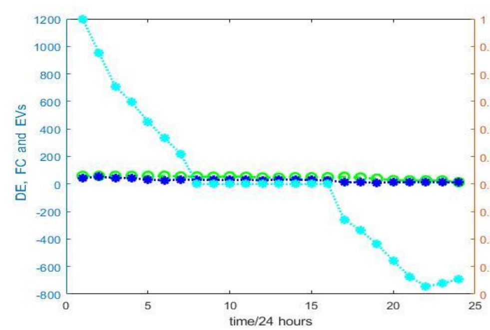
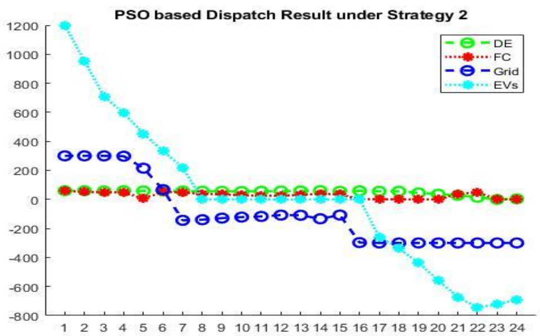




*fig 0.257 summer load with RTEP tariff coordinated 544 EV grid connected PSO connected PSO*

*fig 0.258 summer load with RTEP tariff coordinated 544 EV grid*



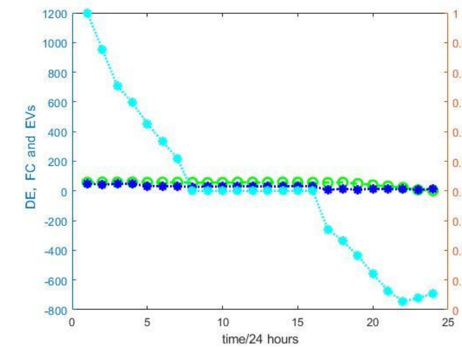
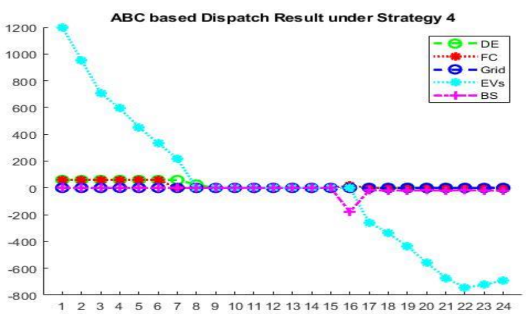




*fig 0.259 summer load with TOU tariff coordinated 544 EV grid connected PSO connected PSO*

*fig 0.260 summer load with TOU tariff coordinated 544 EV grid*



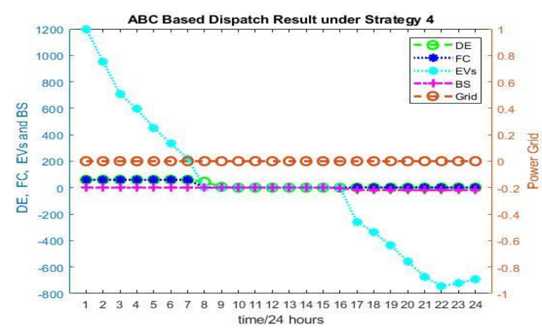
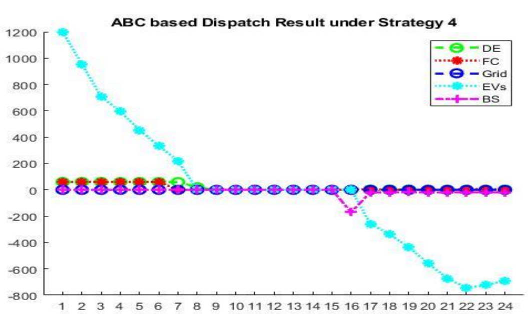




*fig 0.261 coordinated 544 EV islanded CPP tariff unscheduled load*

*fig 0.262 coordinated 544 EV islanded CPP tariff unscheduled load*



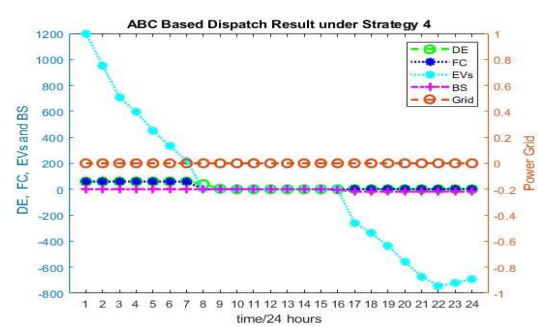
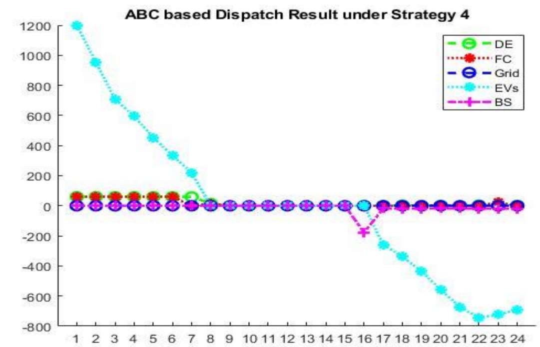



*fig 0.263 unscheduled load with RTEP tariff coordinated 544 EV islanded*

*fig 0.280 unscheduled load with RTEP tariff coordinated 544 EV islanded*



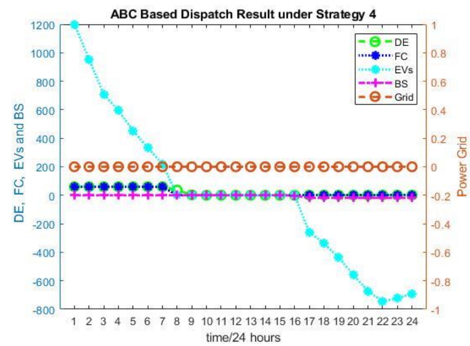
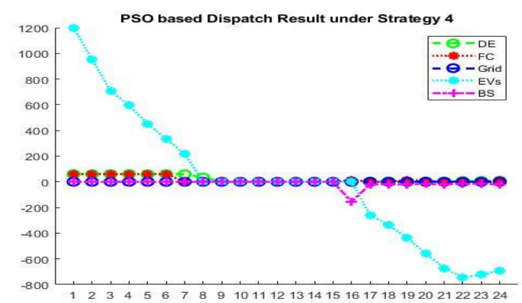




*fig 0.264 unscheduled load with TOU tariff coordinated 544 EV islanded*

*fig 0.265 unscheduled load with TOU tariff coordinated 544 EV islanded*



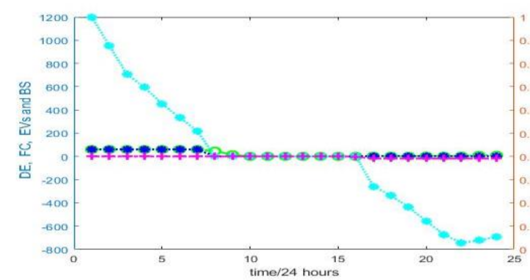
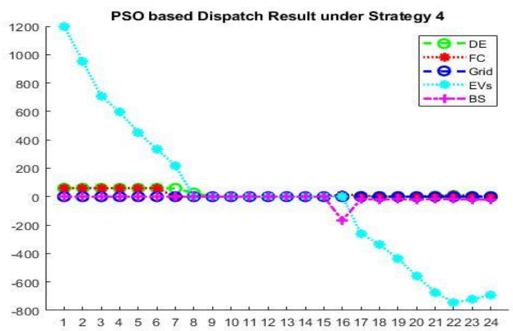




*fig 0.266 summer unscheduled load with CPP tariff coordinated 544 EV islanded PSO islanded PSO*

*fig 0.267 summer unscheduled load with CPP tariff coordinated 544 EV*



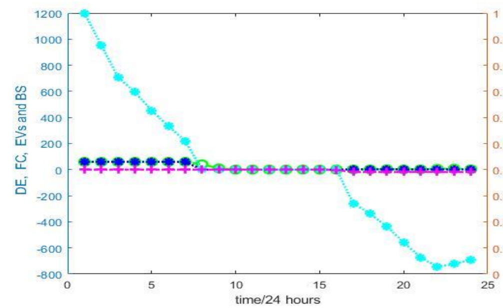
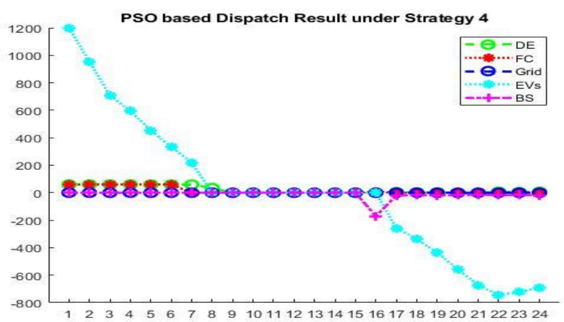




*fig 0.268 summer unscheduled load with RTEP tariff coordinated 544 EV islanded PSO EV islanded PSO*

*fig 0.269 summer unscheduled load with RTEP tariff coordinated 544*



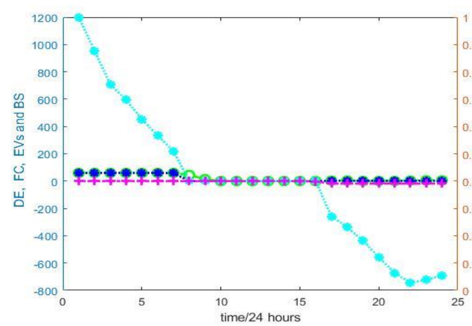




*fig 0.270 summer unscheduled load with TOU tariff coordinated 544 EV islanded PSO islanded PSO*

*fig 0.271 summer unscheduled load with TOU tariff coordinated 544 EV*

## Summer scheduled load:

Winter unscheduled load is taken to examine the performance of PSO and ABC algorithms with three different tariffs i.e., TOU, RTEP and CPP.

### Autonomous 80 EVs:

Considering autonomous 80 EVs, when Scheduling strategy-1 is selected to inspect the performance of PSO and ABC algorithms for the load. The parameters of PSO and proposed

ABC algorithms are exhibited in Table 13. Looking at the total cost in the table below it is shown that they are decreased using ABC algorithm in TOU and RTEP, whereas in CPP tariff they are decreased using PSO algorithm. Operating cost for TOU and CPP is reduced with PSO algorithm and ABC algorithm reduced the operating cost for RTEP tariff. Pollutant emissions for TOU and CPP are reduced in ABC algorithm and for RTEP it is reduced in PSO algorithm. For less carbon dioxide emissions ABC is used for TOU and CPP tariffs and PSO is used for RTEPs.

In case of Scheduling strategy 3, all the parameters i.e., total cost, operating cost, pollutant emissions and CO2 emissions are decreased using ABC in TOU tariff. For RTEP tariff total cost and operating cost is reduced in PSO and pollutant emissions and CO2 emissions are reduced in ABC algorithm. And in CPP tariff they are all reduced by PSO algorithm.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 1 Grid connected | C1 | 265.2978 | 138.8281 | 256.6489 | 243.5315 | 348.1891 | 93.4258 |
| | C2 | 11.4413 | 115.6117 | 4.18522 | 467.4449 | 91.4936 | 139.7442 |
| | C3 | 127.4572 | 142.9913 | 134.5592 | 184.5672 | 122.8735 | 147.7391 |
| | C | 185.1811 | 133.2672 | 177.1772 | 294.6716 | 258.1948 | 114.8217 |
| 3 Islanded | C1 | 1359.1228 | 1399.9479 | 1348.2747 | 1392.5869 | 1375.7924 | 1343.5497 |
| | C2 | 45.1771 | 75.7369 | 47.4771 | 84.792 | 93.9489 | 34.1538 |
| | C3 | 44.6267 | 46.9344 | 44.4693 | 46.9725 | 47.2453 | 38.2928 |
| | C | 881.6841 | 916.2433 | 875.2437 | 912.8645 | 945.583 | 868.6723 |

*Table 13 Summer load with autonomous 84 EV*

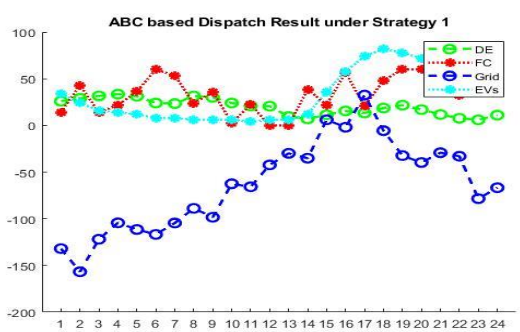



*fig 0.272 summer CPP load with CPP tariff autonomous 84 EV grid connected grid connected*

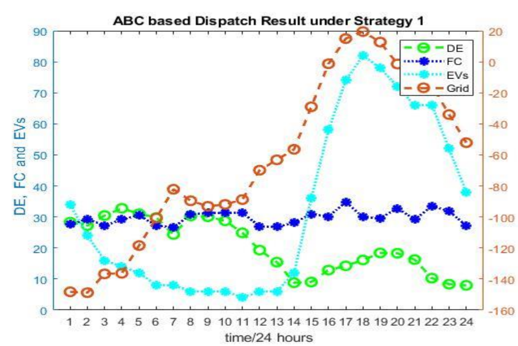



*fig 0.290 summer CPP load with CPP tariff autonomous 84 EV*

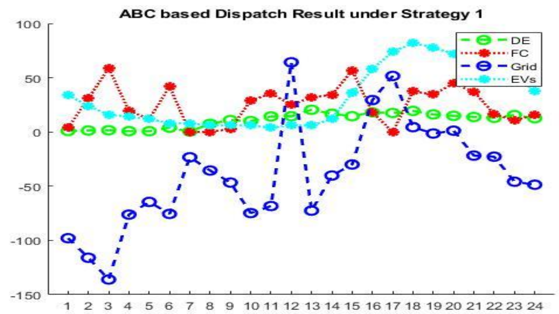



*fig 0.273 summer RTEP load with RTEP tariff autonomous 84 EV grid connected grid connected*

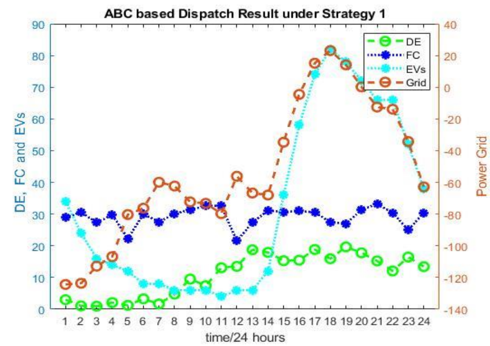



*fig 0.274 summer RTEP load with RTEP tariff autonomous 84 EV*

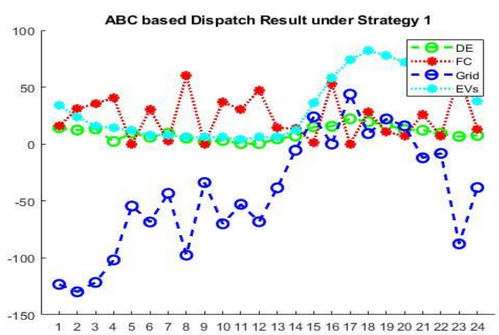



*fig 0.275 summer TOU load with TOU tariff autonomous 84 EV grid connected connected*

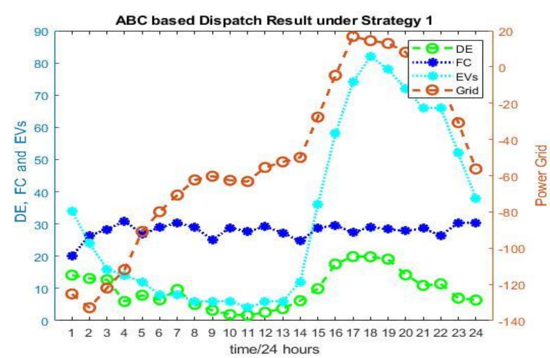
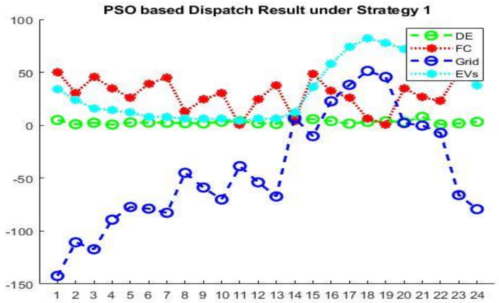



*fig 0.276 summer TOU load with TOU tariff autonomous 84 EV grid*



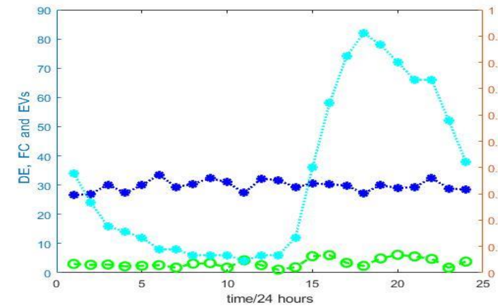
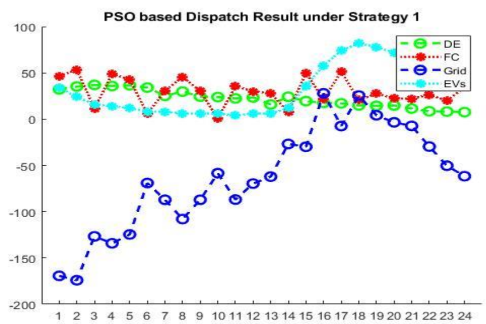




*fig 0.277 summer load with CPP tariff autonomous 84 EV grid connected PSO connected PSO*

*fig 0.278 summer load with CPP tariff autonomous 84 EV grid*



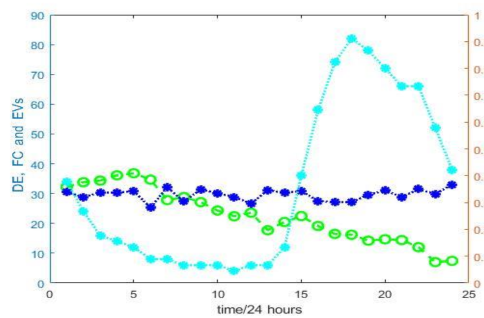
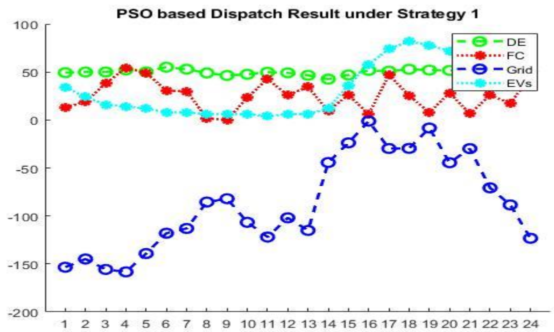




*fig 0.279 summer load with RTEP tariff autonomous 84 EV grid connected PSO PSO*

*fig 0.280 summer load with RTEP tariff autonomous 84 EV grid connected*



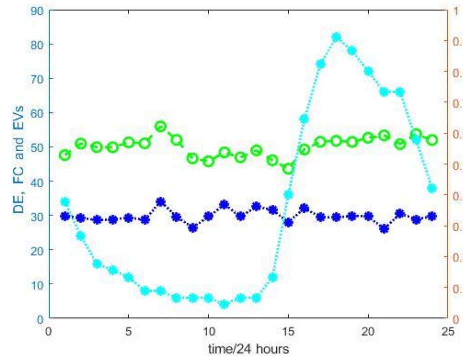
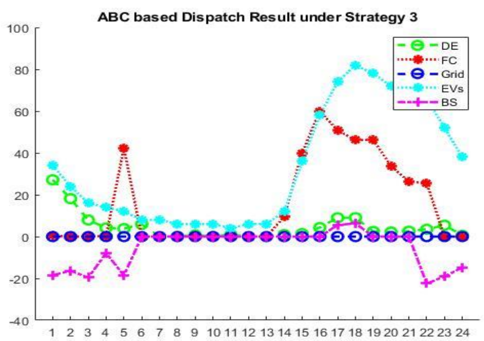




*fig 0.281 summer load with TOU tariff autonomous 84 EV grid connected PSO connected PSO*

*fig 0.300 summer load with TOU tariff autonomous 84 EV grid*



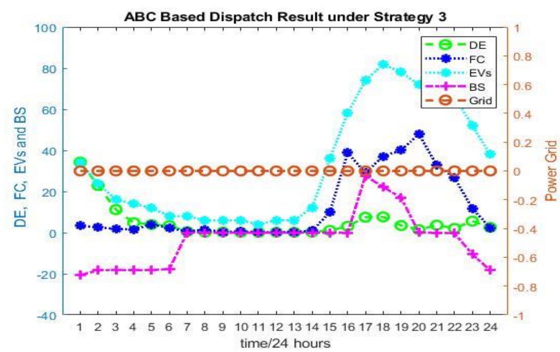
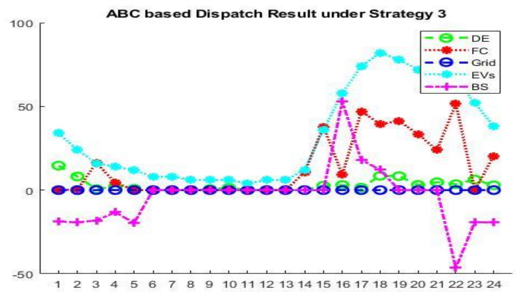




*fig 0.282 summer CPP load with CPP tariff autonomous 84 EV islanded islanded*

*fig 0.283 summer CPP load with CPP tariff autonomous 84 EV*



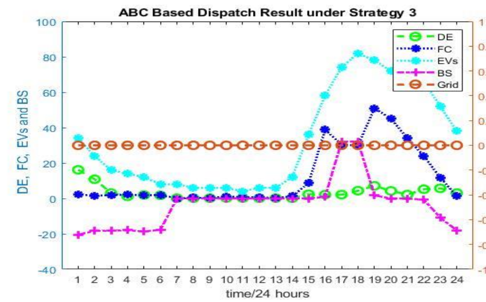
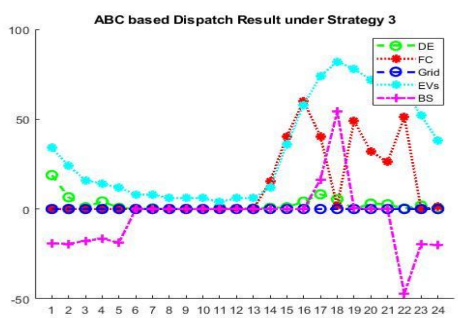




*fig 0.284 summer RTEP load with RTEP tariff autonomous 84 EV islanded islanded*

*fig 0.285 summer RTEP load with RTEP tariff autonomous 84 EV*



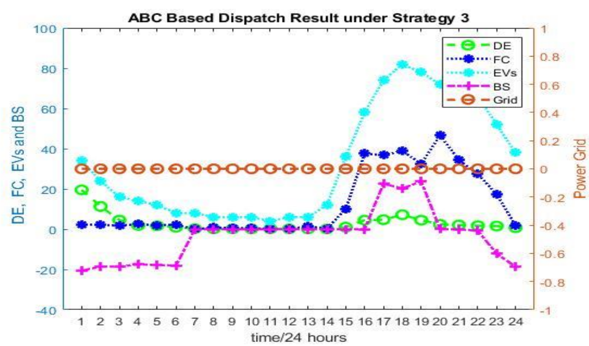
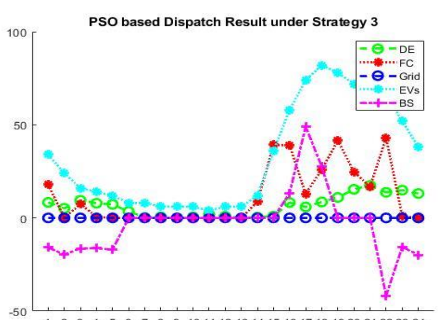




*fig 0.286 summer TOU load with TOU tariff autonomous 84 EV islanded islanded*

*fig 0.287 summer TOU load with TOU tariff autonomous 84 EV*



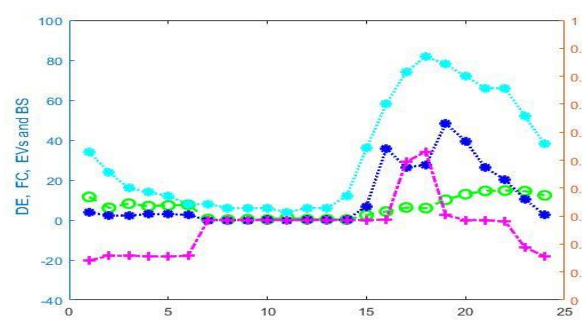
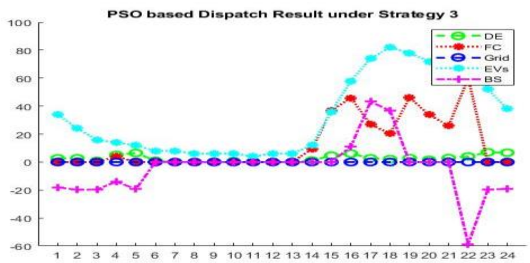



*fig 0.288 summer load with CPP tariff autonomous 84 EV islanded PSO PSO*

*fig 0.289 summer load with CPP tariff autonomous 84 EV islanded*



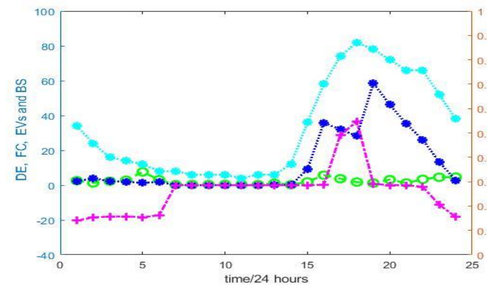
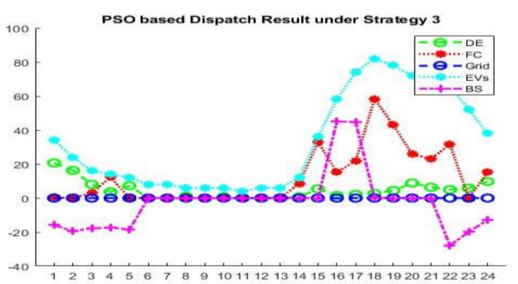




*fig 0.290 summer load with RTEP Tarif autonomous 84 EV islanded PSO PSO*

*fig 0.310 summer load with RTEP Tarif autonomous 84 EV islanded*



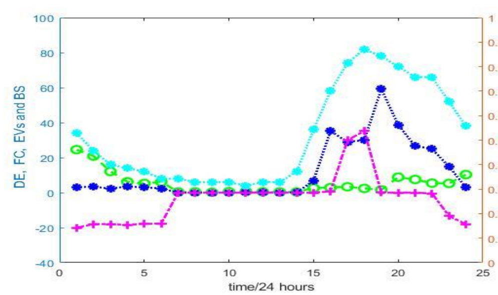




*fig 0.291 summer load with TOU Tarif autonomous 84 EV islanded PSO*

*fig 0.292 summer load with TOU Tarif autonomous 84 EV islanded PSO*

## Autonomous 500 EVs:

Considering autonomous 500 EVs, when Scheduling strategy-1 is chosen to investigate the performance of PSO and ABC algorithms for the unscheduled load. The parameters of PSO and proposed ABC algorithms are exhibited in Table 14. Looking at the total cost and operating cost in the table below it is shown that they are decreased using PSO algorithm in RTEP and CPP tariffs whereas in TOU tariff they are decreased using ABC algorithm. Pollutant emissions for TOU are reduced in PSO algorithm and for RTEP and CPP it is reduced in ABC algorithm. For less carbon dioxide emissions PSO is used for RTEP and CPP tariffs and ABC is used for TOU.

In case of Scheduling strategy 3, all the parameters i.e., total cost, operating cost, pollutant emissions and CO2 emissions are decreased using ABC in RTEP and CPP tariffs and in TOU they are reduced by PSO.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 1 Grid connected | C1 | 5162.7119 | 5344.8879 | 5257.7326 | 5378.4949 | 4946.9381 | 5478.4984 |
| | C2 | 719.5221 | 534.2493 | 647.642 | 514.5626 | 986.1569 | 834.4463 |
| | C3 | 499.5211 | 517.6462 | 546.6523 | 521.7564 | 482.9759 | 495.3436 |
| | C | 3526.7999 | 3595.84 | 3559.1761 | 3613.3859 | 3456.4915 | 3542.435 |
| 3 Islanded | C1 | 2769.3448 | 2745.4226 | 2824.5239 | 2763.6437 | 2757.8373 | 2855.1567 |
| | C2 | 516.9434 | 541.6548 | 555.4195 | 512.466 | 514.5485 | 573.4527 |
| | C3 | 193.2331 | 189.8346 | 241.4447 | 192.285 | 192.1487 | 245.5797 |
| | C | 1917.8426 | 1898.2873 | 1963.7774 | 1912.8144 | 1949.7579 | 1988.2786 |

*Table 14 summer load with autonomous 544 EV*

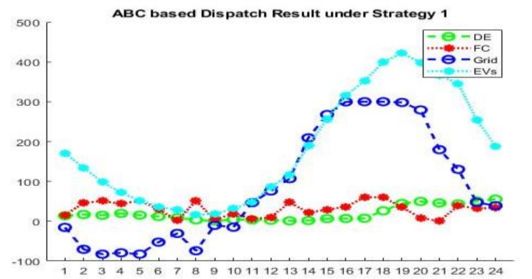



*fig 0.293 summer CPP load with CPP tariff autonomous 544 EV grid connected connected*

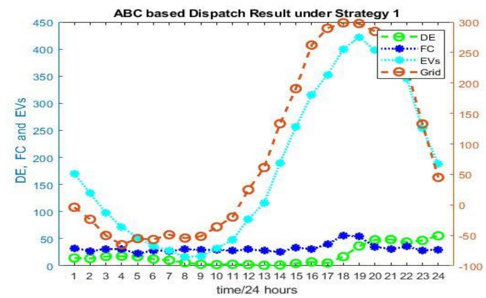



*fig 0.294 summer CPP load with CPP Tarif autonomous 544 EV grid*

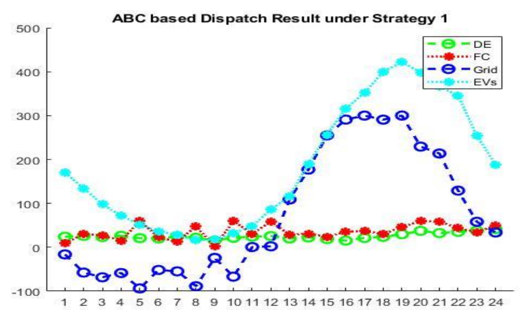



*fig 0.295 summer RTEP load with RTEP tariff autonomous 544 EV grid connected connected*

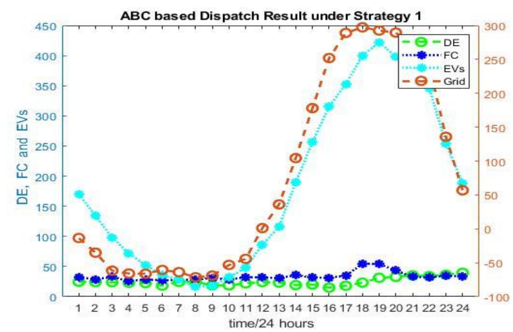



*fig 0.296 summer RTEP load with RTEP Tarif autonomous 544 EV grid*

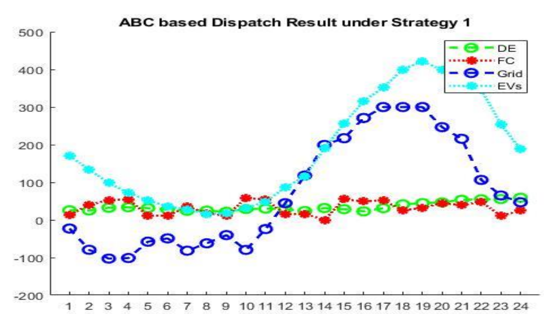



*fig 0.297 summer TOU load with TOU tariff autonomous 544 EV grid connected*

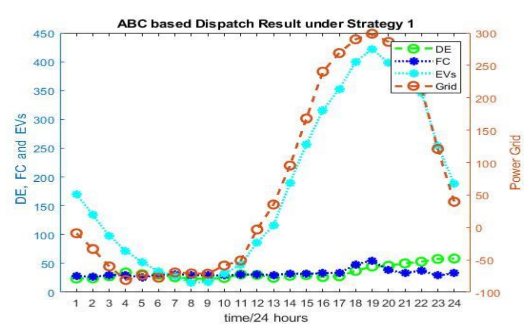
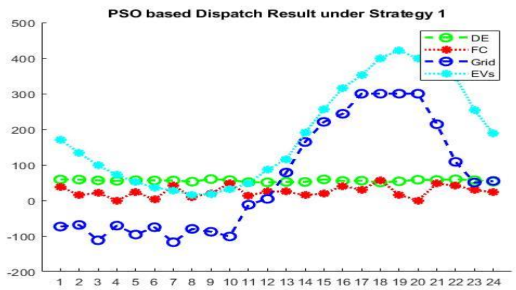



*fig 0.298 summer TOU load with TOU Tarif autonomous 544 EV grid*

*connected*



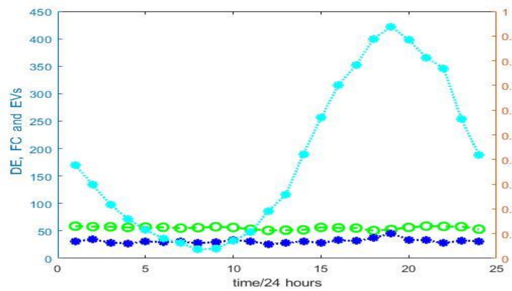
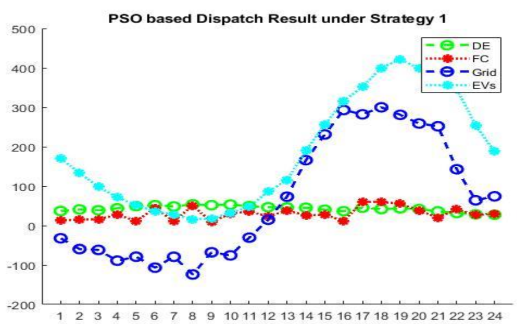




*fig 0.299 summer load with CPP tariff autonomous 544 EV grid connected PSO connected PSO*

*fig 0.320 summer load with CPP Tarif autonomous 544 EV grid*



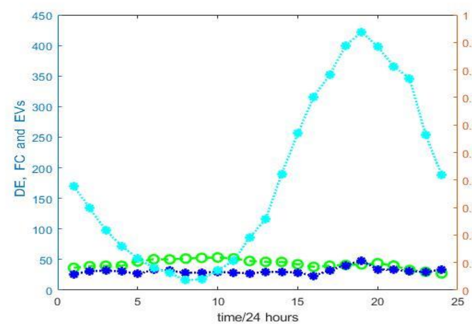
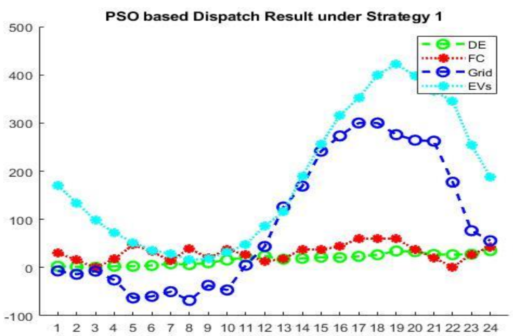




*fig 0.300 summer load with RTEP tariff autonomous 544 EV grid connected PSO connected PSO*

*fig 0.301 summer load with RTEP Tarif autonomous 544 EV grid*



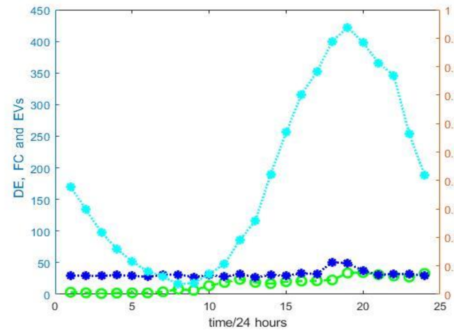
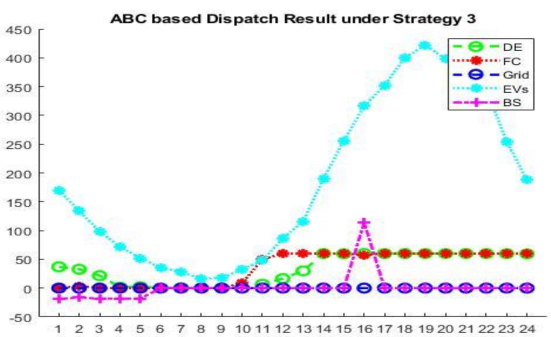




*fig 0.302 summer load with TOU tariff autonomous 544 EV grid connected PSO connected PSO*

*fig 0.303 summer load with TOU Tarif autonomous 544 EV grid*



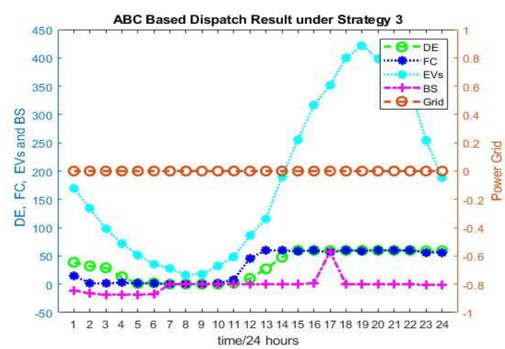




*fig 0.304 summer CPP load with CPP tariff autonomous 544 EV islanded islanded*

*fig 0.305 summer CPP load with CPP Tarif autonomous 544 EV*

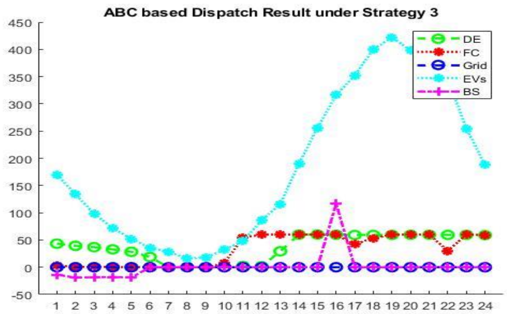



*fig 0.306 summer RTEP load with RTEP tariff autonomous 544 EV islanded islanded*

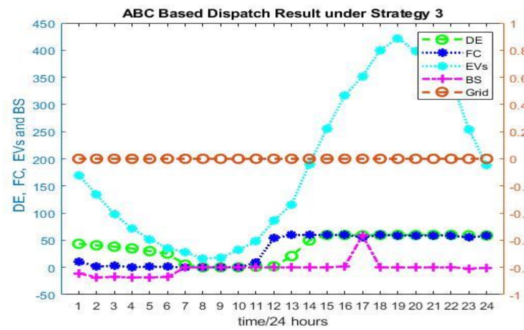



*fig 0.307 summer RTEP load with RTEP Tarif autonomous 544 EV*

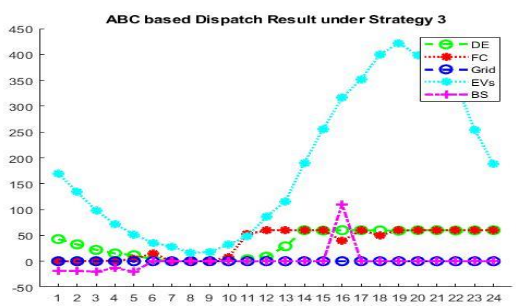



*fig 0.308 summer load with TOU tariff autonomous 544 EV islanded*

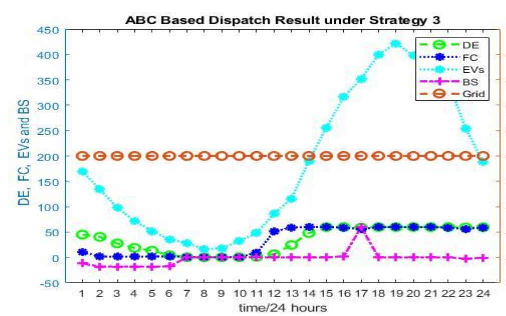
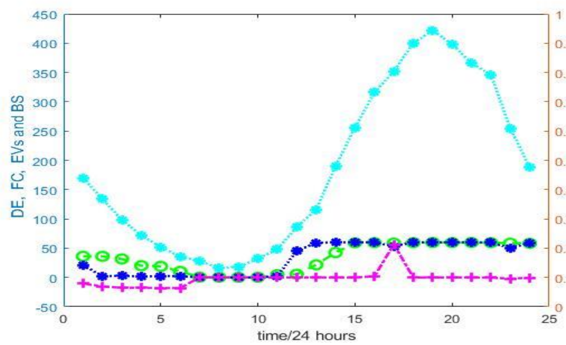



*fig 0.330 summer load with TOU tariff autonomous 544 EV islanded*



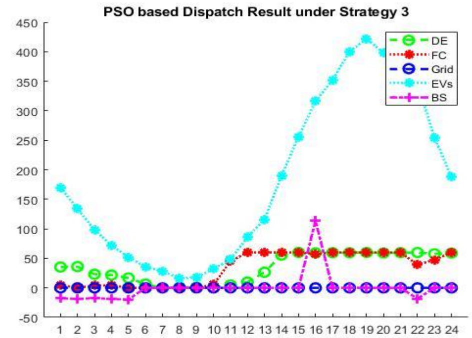
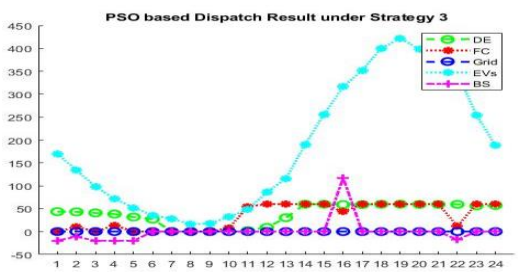




*fig 0.309 summer load with CPP tariff autonomous 544 EV islanded PSO PSO*

*fig 0.310 summer load with CPP tariff autonomous 544 EV islanded*



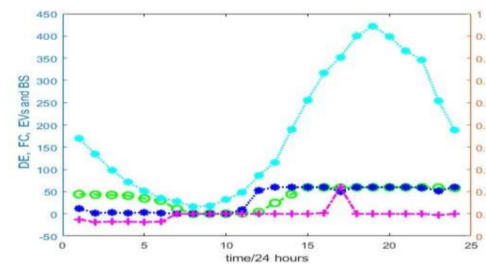
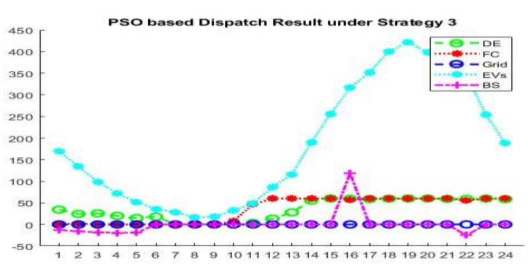




*fig 0.311 summer load with RTEP tariff autonomous 544 EV islanded PSO islanded PSO*

*fig 0.312 summer load with RTEP tariff autonomous 544 EV*



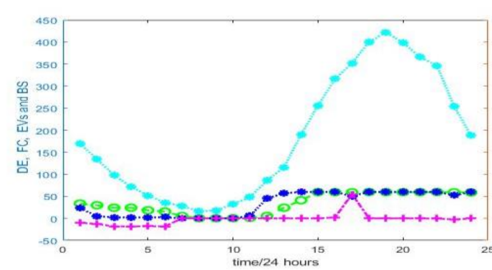




*fig 0.313 summer load with TOU tariff autonomous 544 EV islanded PSO PSO*

*fig 0.314 summer load with TOU tariff autonomous 544 EV islanded*

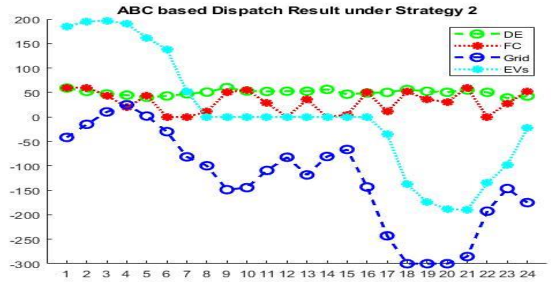
**Coordinated 80 EVs:**

Considering coordinated 80 EVs, when Scheduling strategy-1 is chosen to probe the execution of PSO and ABC algorithms. The constraints of PSO and proposed ABC algorithms are divulged in Table 15. Looking at the total cost and operating cost in the table below it is shown that they are decreased using ABC algorithm in all tariffs. Pollutant emissions for TOU and CPP are reduced in ABC algorithm and for RTEP it is reduced in PSO algorithm. For less carbon dioxide emissions ABC algorithm in all tariffs is used.

In case of Scheduling strategy 3, all the parameters i.e., total cost, operating cost, pollutant emissions and CO2 emissions are decreased using ABC in TOU and RTEP tariffs. And in CPP they are reduced by PSO algorithm except operating cost, which is less in ABC algorithm.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 2 Gris connected | C1 | 814.9588 | 1166.2965 | 972.6552 | 948.4639 | 1197.2112 | 1486.423 |
| | C2 | 36.4956 | 444.4422 | 185.3844 | 115.3755 | 397.412 | 282.2421 |
| | C3 | 262.6552 | 295.2368 | 278.3842 | 273.1628 | 341.2813 | 294.4861 |
| | C | 553.4443 | 878.2992 | 696.6119 | 636.8384 | 896.7159 | 795.1139 |
| 4 Islanded | C1 | 1542.7689 | 1571.6974 | 1554.4833 | 1642.3974 | 1592.8338 | 1569.2216 |
| | C2 | 186.4553 | 145.4834 | 172.596 | 195.6314 | 189.3547 | 126.3526 |
| | C3 | 69.3634 | 66.8878 | 68.6922 | 74.659 | 73.2848 | 64.5779 |
| | C | 1438.4642 | 1445.7527 | 1441.9795 | 1479.4755 | 1471.2179 | 1438.9924 |

*Table 15 Summer load with coordinated 84 EV*



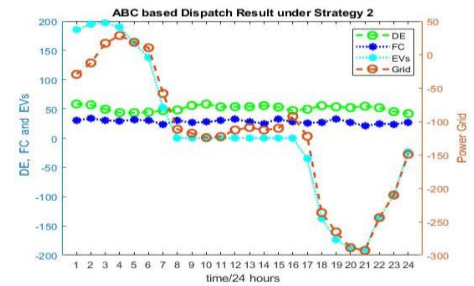
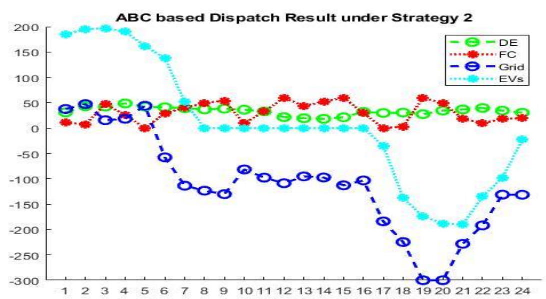




*fig 0.315 summer CPP load with CPP tariff coordinated 84 EV grid connected connected*

*fig 0.316 summer CPP load with CPP tariff coordinated 84 EV grid*



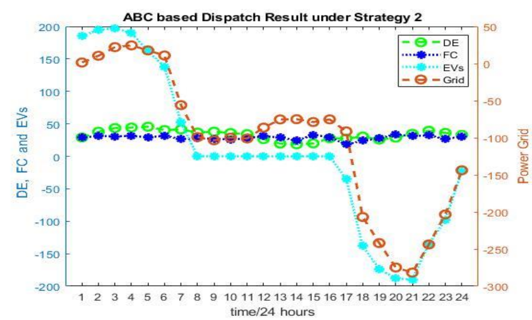
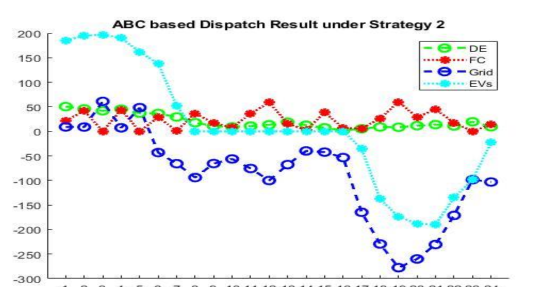




*fig 0.317 summer RTEP load with RTEP tariff coordinated 84 EV grid connected grid connected*

*fig 0.340 summer RTEP load with RTEP tariff coordinated 84 EV*



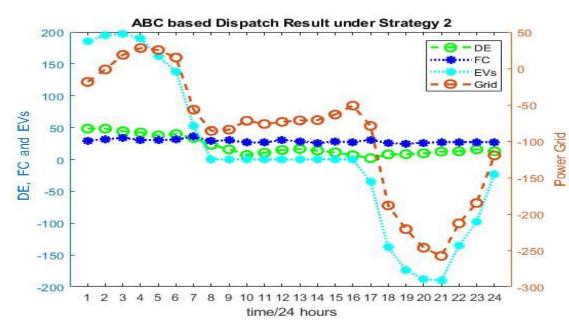
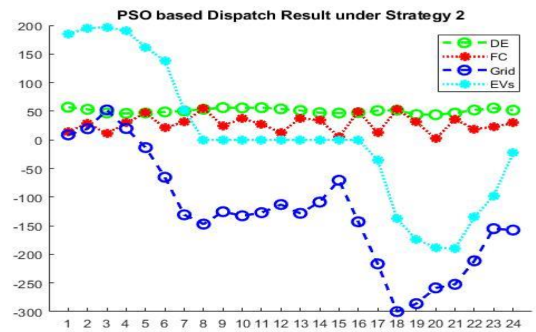




*fig 0.318 Summerton load with TOU tariff coordinated 84 EV grid connected connected*

*fig 0.319 summer TOU load with TOU tariff coordinated 84 EV grid*



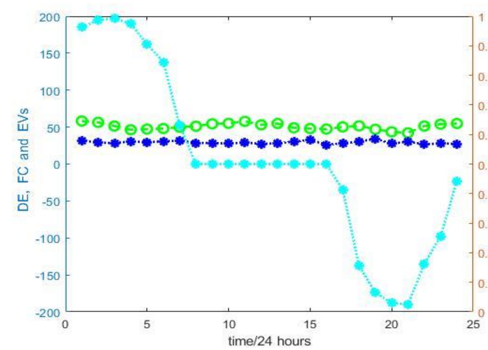
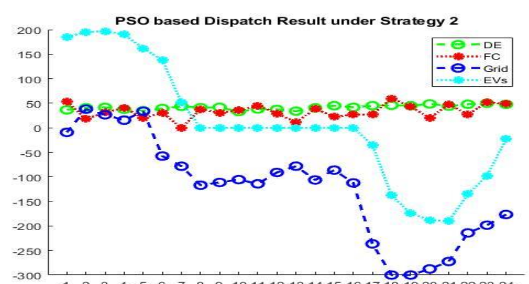




*fig 0.320 summer load with CPP tariff coordinated 84 EV grid connected PSO connected PSO*

*fig 0.321 summer load with CPP tariff coordinated 84 EV grid*



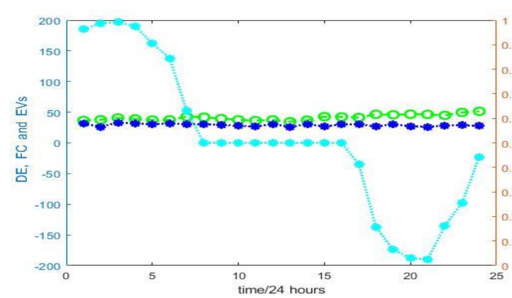
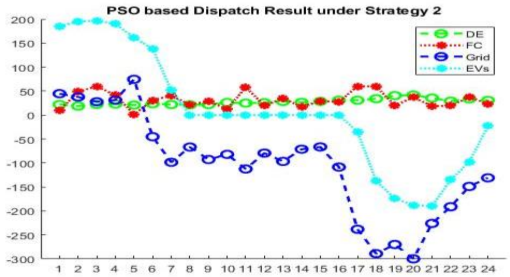




*fig 0.322 summer load with RTEP tariff coordinated 84 EV grid connected PSO PSO*

*fig 0.323 summer load with RTEP tariff coordinated 84 EV grid connected*



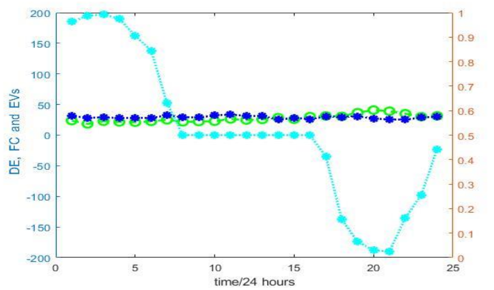
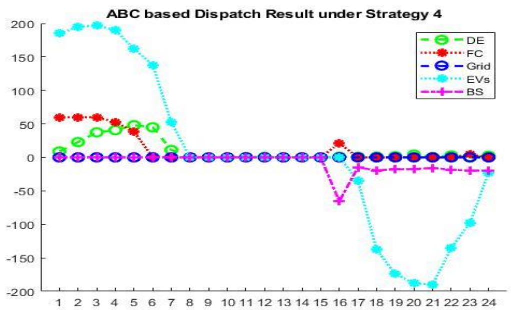




*fig 0.324 summer load with TOU tariff coordinated 84 EV grid connected PSO*
*connected PSO*

*fig 0.325 summer load with TOU tariff coordinated 84 EV grid*



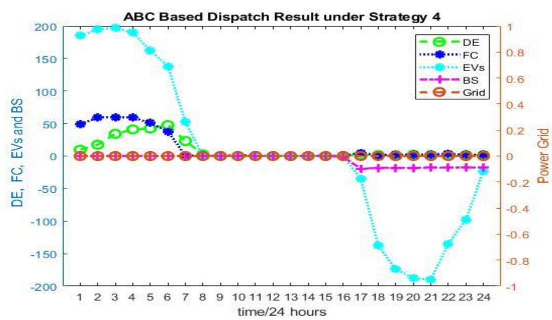
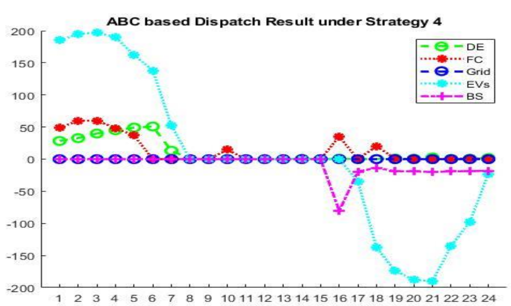




*fig 0.326 summer CPP load with CPP tariff coordinated 84 EV islanded*
*islanded*

*fig 0.350 summer CPP load with CPP tariff coordinated 84 EV*



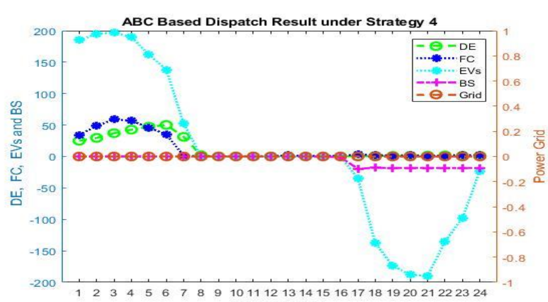




*fig 0.327 summer RTEP load with RTEP tariff coordinated 84 EV islanded*

*fig 0.328 summer RTEP load with RTEP tariff coordinated 84 EV islanded*

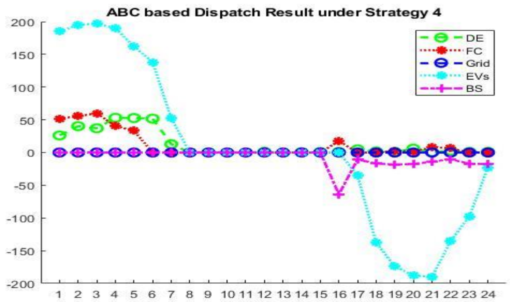



*fig 0.329 summer TOU load with TOU tariff coordinated 84 EV islanded*

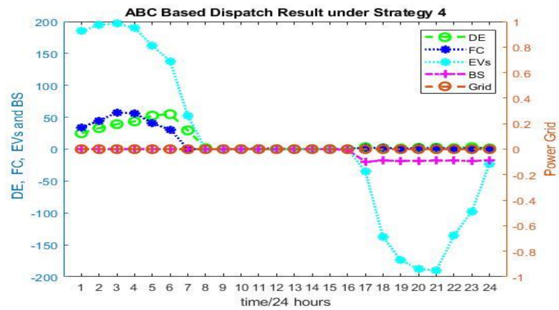



*fig 0.330 summer TOU load with TOU tariff coordinated 84 EV islanded*

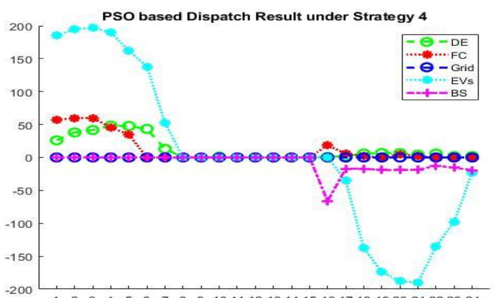



*fig 0.331 summer load with CPP tariff coordinated 84 EV islanded PSO*

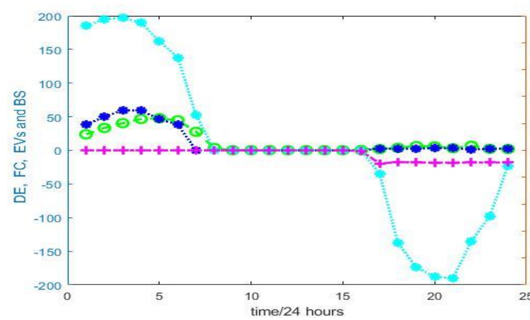



*fig 0.332 summer load with CPP tariff coordinated 84 EV islanded PSO*

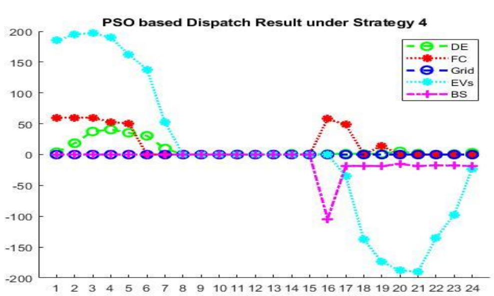



*fig 0.333 summer load with RTEP tariff coordinated 84 EV islanded PSO*

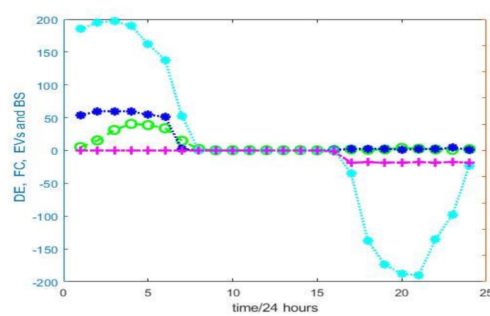
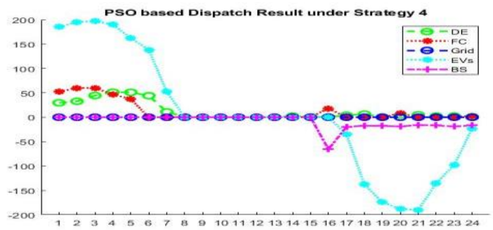



*fig 0.334 summer load with RTEP tariff coordinated 84 EV islanded PSO*



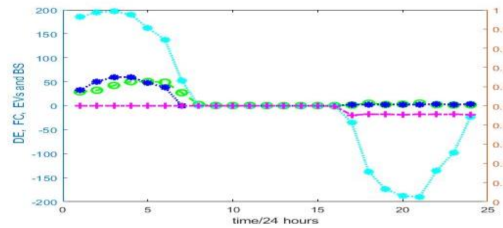




*fig 0.335 summer load with TOU tariff coordinated 84 EV islanded PSO*

*fig 0.360 summer load with TOU tariff coordinated 84 EV islanded PSO*

**Coordinated 500 EVs:**

Cogitating autonomous 500 EVs, when Scheduling strategy-1 is desired to scrutinize the rendition of PSO and ABC algorithms. The parameters of PSO and suggested ABC algorithms are divulged in Table 16. Looking at the total cost, operating cost, and pollutant emissions in the table below it is shown that they are decreased using ABC algorithm in TOU and CPP tariffs whereas in RTEP tariff they are decreased using PSO algorithm. For less carbon dioxide emissions PSO is used for TOU and CPP tariffs and ABC is used for RTEPs.

In case of Scheduling strategy 3 total cost and operating cost are decreased using ABC in all tariffs. Pollutant emissions for RTEP and CPP tariffs are less in ABC algorithm and in TOU they are reduced by PSO. Carbon dioxide emissions are equal in both algorithms for TOU tariff, and for RTEP and CPP tariff it is less in ABC algorithm.

| Scheduling scheme | Quality | ABC | | | PSO | | |
|---|---|---|---|---|---|---|---|
| | | TOU | CPP | RTEP | TOU | CPP | RTEP |
| 2 Grid connected | C1 | 297.6994 | 347.4677 | 296.951 | 386.8348 | 221.9689 | 462.1633 |
| | C2 | 369.4727 | 421.3825 | 361.6113 | 524.1845 | 385.6946 | 487.293 |
| | C3 | 148.3963 | 145.6757 | 147.3153 | 94.5255 | 124.6747 | 85.3147 |
| | C | 296.3151 | 315.7643 | 293.7979 | 391.7474 | 253.6523 | 429.1978 |
| 4 Islanded | C1 | 1927.5161 | 1939.6667 | 1934.5492 | 1935.6999 | 1952.4591 | 1975.6852 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | C2 | 297.1111 | 341.5465 | 299.2983 | 295.7548 | 311.2228 | 323.3851 |
| | C3 | 149.4297 | 114.3815 | 149.4888 | 149.4581 | 112.3441 | 115.3759 |
| | C | 1315.986<br>9 | 1325.443<br>7 | 1318.532<br>1 | 1324.893<br>6 | 1335.612<br>9 | 1354.121<br>7 |

*Table 16 Summer load with coordinated 544 EV*

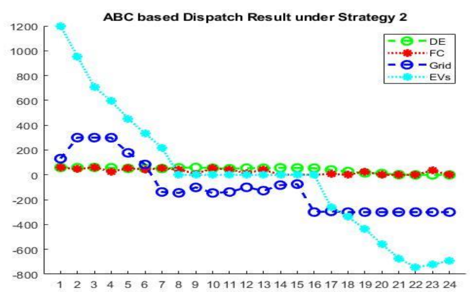



*fig 0.336 summer CPP load with CPP tariff coordinated 544 EV grid connected connected*

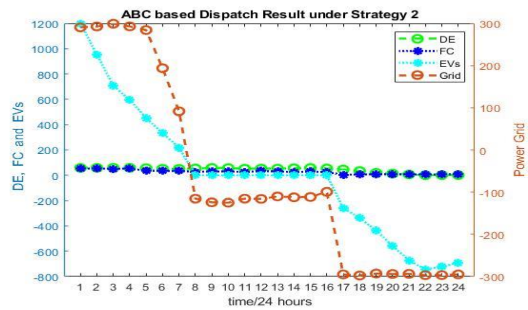



*fig 0.337 summer CPP load with CPP tariff coordinated 544 EV grid*

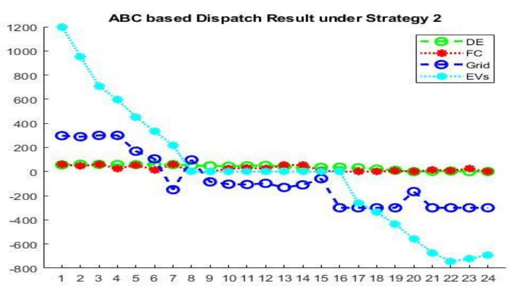



*fig 0.338 summer RTEP load with RTEP tariff coordinated 544 EV grid connected connected*

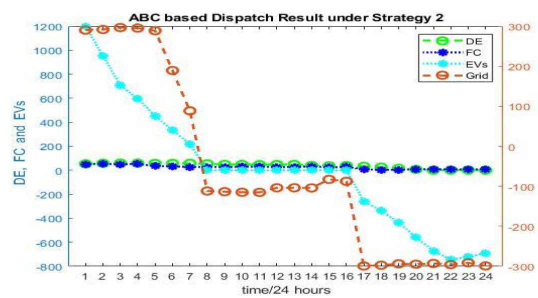



*fig 0.339 summer RTEP load with RTEP tariff coordinated 544 EV grid*

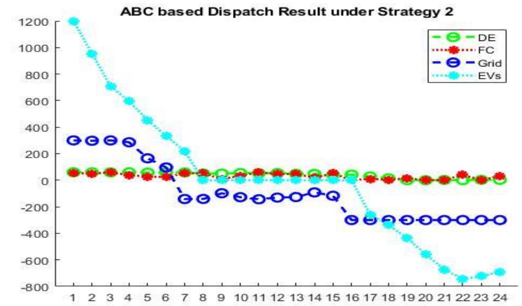



*fig 0.340 summer TOU load with TOU tariff coordinated 544 EV grid connected connected*

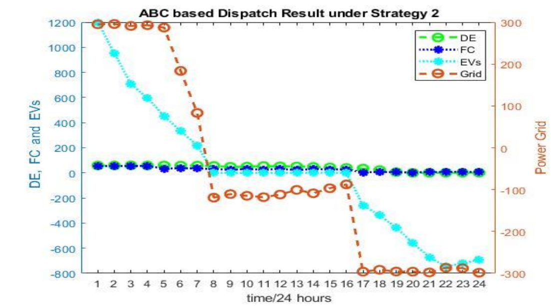



*fig 0.341 summer TOU load with TOU tariff coordinated 544 EV grid*

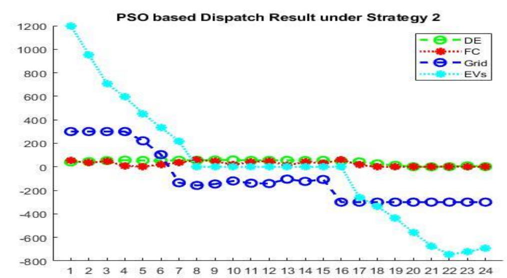



*fig 0.342 summer load with CPP tariff coordinated 544 EV grid connected PSO PSO*

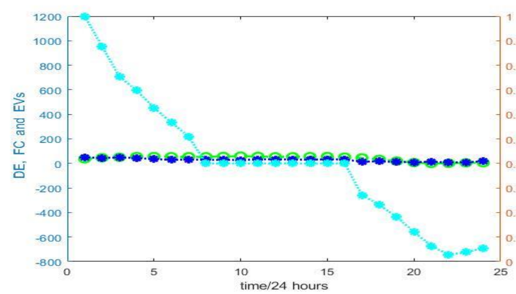



*fig 0.343 summer load with CPP tariff coordinated 544 EV grid connected*

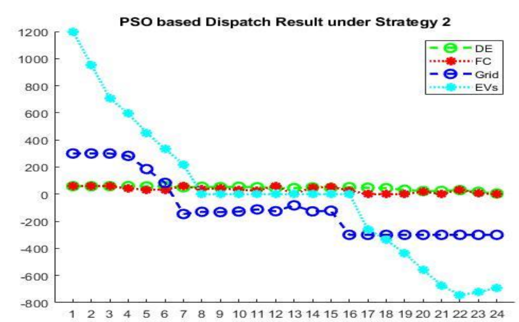



*fig 0.344 summer load with RTEP tariff coordinated 544 EV grid connected PSO PSO*

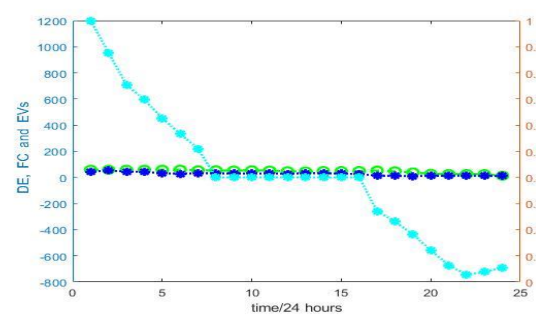



*fig 0.370 summer load with RTEP tariff coordinated 544 EV grid connected*

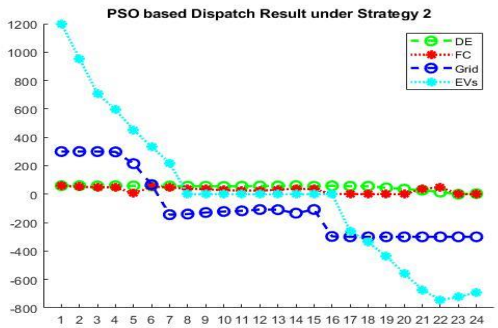



*fig 0.345 summer load with TOU tariff coordinated 544 EV grid connected PSO*

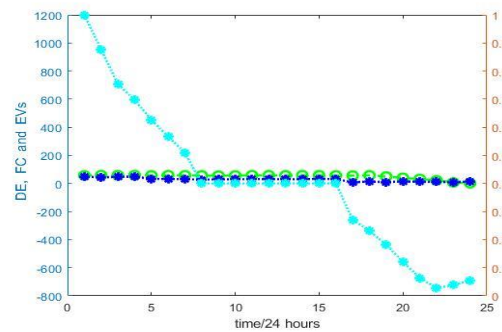



*fig 0.346 summer load with TOU tariff coordinated 544 EV grid connected PSO*

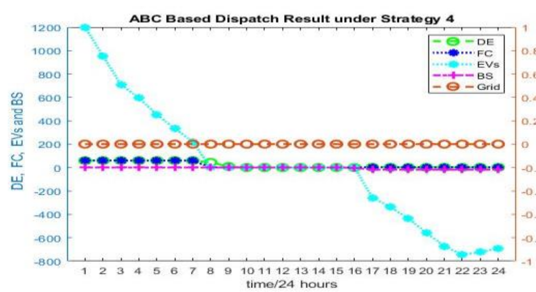



*fig 0.347 summer CPP load with CPP tariff coordinated 544 EV islanded*

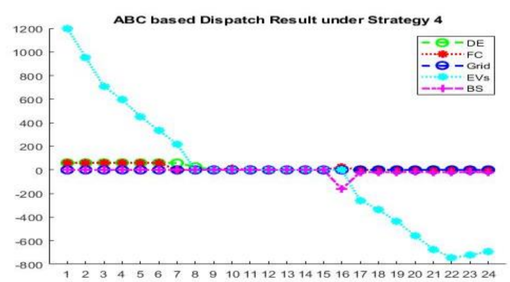
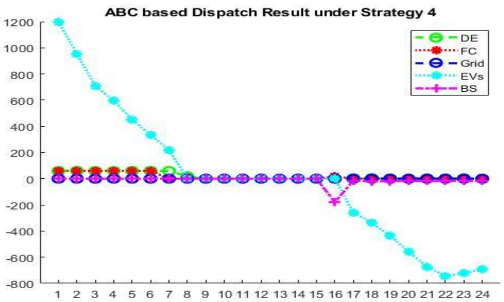



*fig 0.348 summer CPP load with CPP tariff coordinated 544 EV islanded*



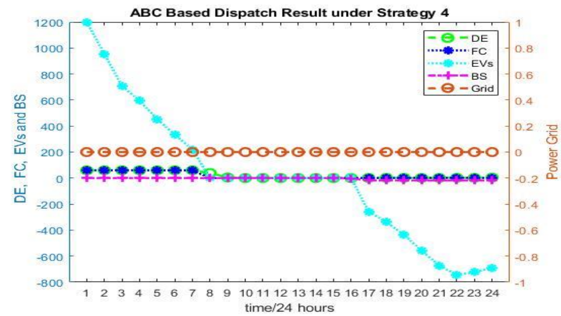
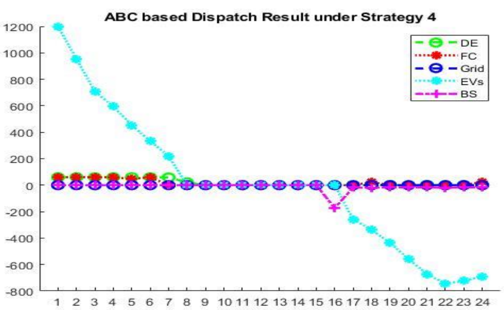




*fig 0.349 summer RTEP load with RTEP tariff coordinated 544 EV islanded*

*fig 0.350 summer RTEP load with RTEP tariff coordinated 544 EV islanded*



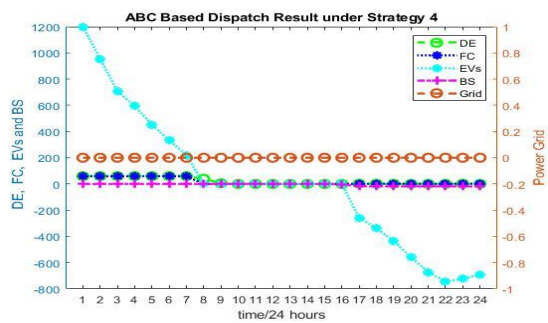
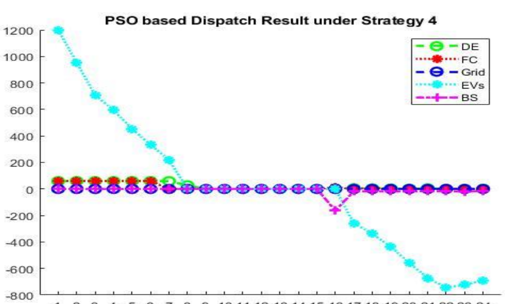




*fig 0.351 summer TOU load with TOU tariff coordinated 544 EV islanded islanded*

*fig 0.352 summer TOU load with TOU tariff coordinated 544 EV*



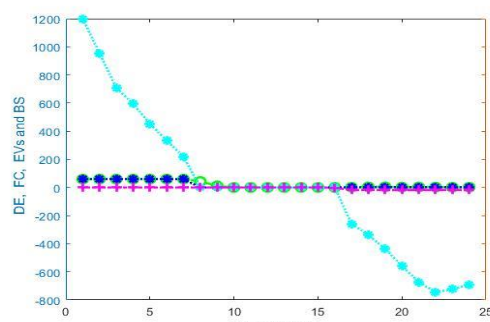
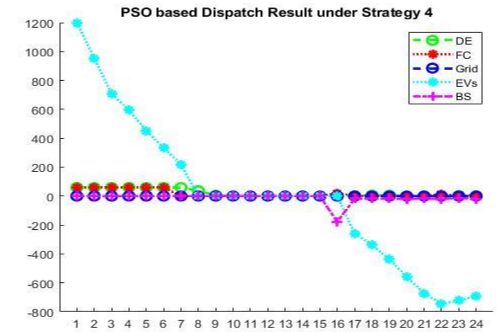




*fig 0.353 summer load with CPP tariff coordinated 544 EV islanded PSO PSO*

*fig 0.380 summer load with CPP tariff coordinated 544 EV islanded*



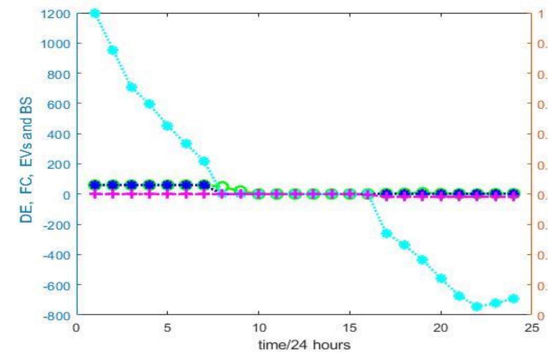
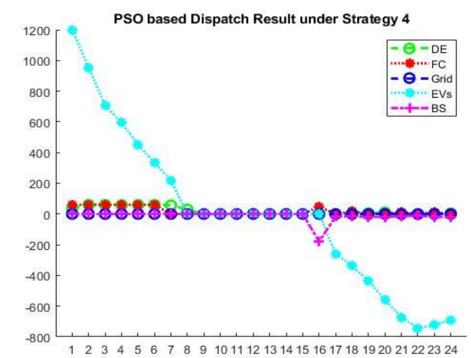




*fig 0.354 summer load with RTEP tariff coordinated 544 EV islanded PSO*

*fig 0.355 summer load with RTEP tariff coordinated 544 EV islanded*



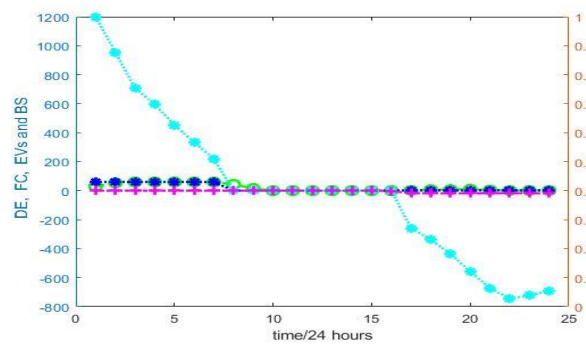




*fig 0.356 summer load with TOU tariff coordinated 544 EV islanded PSO*

*fig 0.357 summer load with TOU tariff coordinated 544 EV islanded PSO*

# Chapter 5

# Conclusion

# CHAPTER 5

# CONCLUSION AND FUTURE WORK

In this research demand response program is used along with joint optimization approach for planning and operation of residential MG. Performance of the intended model is examined with and without DSM for summer as well as winter load. Two algorithms i.e., PSO and ABC are used to validate the MG planning and operation optimization models while comparing results of both algorithms.

By and large evaluation of results shows that the proposed planning and operation modeling approach can give great deals while amplifying RERs and EVs coordination with the help of DR programs.

# References

[1] O. Hafez and K. Bhattacharya, "Optimal planning and design of a renewable energy-based supply system for microgrids," *Renewable Energy*, vol. 45, pp. 7–15, 2012, doi: 14.1416/J.RENENE.2412.41.487.

[2] Q. Fu *et al.*, "Microgrid generation capacity design with renewables and energy storage addressing power quality and surety," *IEEE Transactions on Smart Grid*, vol. 3, no. 4, pp. 2419–2427, 2012, doi:14.1149/TSG.2412.2223245.

[3] P. Palensky and D. Dietrich, "Demand side management: Demand response, intelligent energy systems, and smart loads," *IEEE Transactions on Industrial Informatics*, vol. 7, no. 3, pp. 381–388, Aug. 2011, doi:14.1149/TII.2411.2158841.

[4] K. Zhou, S. Yang, Z. Chen, and S. Ding, "Optimal load distribution model of microgrid in the smart grid environment," *Renewable and Sustainable Energy Reviews*, vol. 35, pp. 344–314, 2014, doi: 14.1416/J.RSER.2414.44.428.

[5] N. I. Nwulu and X. Xia, "Optimal dispatch for a microgrid incorporating renewables and demand response," *Renewable Energy*, vol. 141, pp. 16–28, Feb. 2017, doi: 14.1416/J.RENENE.2416.48.426.

[6] M. Hosseini Imani, P. Niknejad, and M. R. Barzegaran, "The impact of customers' participation level and various incentive values on implementing emergency demand response program in microgrid operation," *International Journal of Electrical Power and Energy Systems*, vol. 96, pp. 114–125, Mar. 2018, doi: 14.1416/J.IJEPES.2417.49.438.

[7] J. Shen, C. Jiang, Y. Liu, and J. Qian, "A Microgrid Energy Management System with Demand Response for Providing Grid Peak Shaving," *Electric Power Components and Systems*, vol. 44, no. 8, pp. 843–852, May 2016, doi:14.1484/15325448.2416.1138344.

[8] A. Khodaei, S. Bahramirad, and M. Shahidehpour, "Microgrid Planning Under Uncertainty," *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 2417–2425, Sep. 2015, doi:14.1149/TPWRS.2414.2361494.
[9] "Kammen: Renewable energy options for the emerging... - Google Scholar."

https://scholar.google.com/scholar?cluster=246516 4547733394681&hl=en&as_sdt=4,5 (accessed Sep. 26, 2021).

[14] A. Saif, V. Ravikumar Pandi, H. H. Zeineldin, and S. Kennedy, "Optimal allocation of distributed energy resources through simulation-based optimization," *Electric Power Systems Research*, vol. 144, pp. 1–8, 2013, doi: 14.1416/J.EPSR.2413.45.419.

[11] M. Manbachi and M. Ordonez, "AMI-Based Energy Management for Islanded AC/DC Microgrids Utilizing Energy Conservation and Optimization," *IEEE Transactions on Smart Grid*, vol. 14, no. 1, pp. 293–344, Jan. 2019, doi:14.1149/TSG.2417.2737946.

[12] A. Askarzadeh, "A Memory-Based Genetic Algorithm for Optimization of Power Generation in a Microgrid," *IEEE Transactions on Sustainable Energy*, vol. 9, no. 3, pp. 1481–1489, Jul. 2018, doi:14.1149/TSTE.2417.2765483.

[13] M. Marzband, M. Ghadimi, A. Sumper, and J. L. Dominguez-Garcia, "Experimental validation of a real-time energy management system using multiperiod gravitational search algorithm for microgrids in islanded mode," *Applied Energy*, vol. 128, pp. 164–174, Sep. 2014, doi: 14.1416/J.APENERGY. 2414.44.456.

[14] L. Luo *et al.*, "Optimal scheduling of a renewable based microgrid considering photovoltaic system and battery energy storage under uncertainty," *Journal of Energy Storage*, vol. 28, Apr. 2024, doi: 14.1416/J.EST.2424.141346.

[15] F. H. Aghdam, N. T. Kalantari, and B. Mohammadi- Ivatloo, "A chance-constrained energy management in multi-microgrid systems considering degradation cost of energy storage elements," *Journal of Energy Storage*, vol. 29, Jun. 2024, doi: 14.1416/J.EST.2424.141416.

[16] K. Gholami and E. Dehnavi, "A modified particle swarm optimization algorithm for scheduling renewable generation in a micro-grid under load uncertainty," *Applied Soft Computing Journal*, vol. 78, pp. 496–514, May 2019, doi: 14.1416/J.ASOC.2419.42.442.

[17] M. G. M. Abdolrasol, M. A. Hannan, A. Mohamed, U. A. U. Amiruldin, I. B. Z. Abidin, and M. N. Uddin, "An Optimal Scheduling Controller for Virtual Power Plant and Microgrid Integration Using the Binary Backtracking Search Algorithm," *IEEE Transactions on Industry Applications*, vol. 54, no.3, pp. 2834–2844, May 2018, doi:14.1149/TIA.2418.2797121.

[18] M. K. Darabi, H. G. Ganjehlou, A. Jafari, M. Nazari- Heris, G. B. Gharehpetian, and M. Abedi, “Evaluating the Effect of Demand Response Programs (DRPs) on Robust Optimal Sizing of Islanded Microgrids,” *Energies 2421, Vol. 14, Page 5754*, vol. 14, no. 18, p. 5754, Sep. 2021, doi: 14.3394/EN14185754.

[19] M. F. Roslan, M. A. Hannan, P. Jern Ker, R. A.Begum, T. M. Indra Mahlia, and Z. Y. Dong, “Scheduling controller for microgrids energy management system using optimization algorithm in achieving cost saving and emission reduction,” *Applied Energy*, vol. 292, Jun. 2021, doi:14.1416/J.APENERGY.2421.116883.

[24] A. Maleki and A. Askarzadeh, “Optimal sizing of a PV/wind/diesel system with battery storage for electrification to an off-grid remote region: A case study of Rafsanjan, Iran,” *Sustainable Energy Technologies and Assessments*, vol. 7, pp. 147–153, 2014, doi: 14.1416/J.SETA.2414.44.445.

[21] Y. A. Katsigiannis, P. S. Georgilakis, and E. S.Karapidakis, “Hybrid simulated annealing-tabu search method for optimal sizing of autonomous power systems with renewables,” *IEEE Transactions on Sustainable Energy*, vol. 3, no.3, pp. 334–338, 2012, doi:14.1149/TSTE.2412.2184844

[22] U. Akram, M. Khalid, and S. Shafiq, “Optimal sizing of a wind/solar/battery hybrid grid-connected microgrid system,” *IET Renewable Power Generation*, vol. 12, no. 1, pp. 72–84, Jan. 2018, doi:14.1449/IET-RPG.2417.4414.

[23] L. Moretti, L. Meraldi, A. Niccolai, G. Manzolini, and S. Leva, “An innovative tunable rule-based strategy for the predictive management of hybrid microgrids,” *Electronics (Switzerland)*, vol. 14, no. 14, May 2021, doi: 14.3394/ELECTRONICS14141162.

[24] A. Jafari, H. Ganjeh Ganjehlou, T. Khalili, B. Mohammadi-Ivatloo, A. Bidram, and P. Siano, “A Two-Loop Hybrid Method for Optimal Placement and Scheduling of Switched Capacitors in Distribution Networks,” *IEEE Access*, vol. 8, pp. 38892–38946, 2020, doi:14.1149/ACCESS.2424.2975714.

[25] M. A. M. Ramli, H. R. E. H. Bouchekara, and A. S. Alghamdi, “Optimal sizing of PV/wind/diesel hybrid microgrid system using multi-objective selfadaptive differential evolution algorithm,” *Renewable Energy*, vol. 121, pp. 444–411, Jun. 2018, doi: 14.1416/J.RENENE.2418.41.458.

[26] A. Jafari, H. Ganjeh Ganjehlou, F. Baghal Darbandi, B. Mohammdi-Ivatloo, and M. Abapour, “Dynamic and multi-objective reconfiguration of distribution network using a novel hybrid algorithm with parallel

processing capability," *Applied Soft Computing Journal*, vol. 94, May 2424, doi: 14.1416/J.ASOC.2424.146146.

[27] H. Ganjeh Ganjehlou, H. Niaei, A. Jafari, D. O. Aroko, M. Marzband, and T. Fernando, "A novel techno-economic multi-level optimization in homemicrogrids with coalition formation capability," *Sustainable Cities and Society*, vol. 64, Sep. 2020, doi: 14.1416/J.SCS.2424.142241.

[28] F. Ahmad and M. S. Alam, "Optimal Sizing and Analysis of Solar PV, Wind, and Energy Storage Hybrid System for Campus Microgrid," *Smart Science*, vol. 6, no. 2, pp. 154–157, Apr. 2018, doi: 14.1484/23484477.2417.1417445.

[29] M. H. Amrollahi and S. M. T. Bathaee, "Technoeconomic optimization of hybrid photovoltaic/wind generation together with energy storage system in a stand-alone micro-grid subjected to demand response," *Applied Energy*, vol. 242, pp. 66–77, 2017, doi: 14.1416/J.APENERGY.2417.45.116.

[34] R. Belfkira, L. Zhang, and G. Barakat, "Optimal sizing study of hybrid wind/PV/diesel power generation unit," *Solar Energy*, vol. 85, no. 1, pp. 144–114, Jan. 2011, doi: 14.1416/J.SOLENER.2414.14.418.

[31] T. Khalili, H. G. Ganjehlou, A. Bidram, S. Nojavan, and S. Asadi, "Financial Risk-Based Scheduling of Micro grids Accompanied by Surveying the Influence of the Demand Response Program," *Conference Record - Industrial and Commercial Power Systems Technical Conference*, vol. 2421- April, Apr. 2021, doi:14.1149/ICPS51847.2421.9416627.

[32] S. Diaf, D. Diaf, M. Belhamel, M. Haddadi, and A. Louche, "A methodology for optimal sizing of autonomous hybrid PV/wind system," *Energy Policy*, vol. 35, no. 11, pp. 5748–5718, Nov. 2007, doi: 14.1416/J.ENPOL.2447.46.424.

[33] L. Moretti, S. Polimeni, L. Meraldi, P. Raboni, S. Leva, and G. Manzolini, "Assessing the impact of a two-layer predictive dispatch algorithm on design and operation of off-grid hybrid microgrids," *Renewable Energy*, vol. 143, pp. 1439–1453, Dec. 2019, doi: 14.1416/J.RENENE.2419.45.464.

[34] A. Jafari, H. Ganjeh Ganjehlou, T. Khalili, and A. Bidram, "A fair electricity market strategy for energy management and reliability enhancement of islanded multi-microgrids," *Applied Energy*, vol. 274, Jul. 2024, doi: 14.1416/J.APENERGY.2424.115174.

[35] F. A. Bhuiyan, A. Yazdani, and S. L. Primak, “Optimal sizing approach for islanded microgrids,” *IET Renewable Power Generation*, vol. 9, no. 2, pp.166–175, Mar. 2015, doi: 14.1449/IETRPG.2413.4416.

[36] Z. Wang, B. Chen, J. Wang, J. Kim, and M. M. Begovic, “Robust optimization based optimal DG placement in microgrids,” *IEEE Transactions on Smart Grid*, vol. 5, no. 5, pp. 2173–2182, Sep. 2014, doi:14.1149/TSG.2414.2321748.

[37] A. M. Eltamaly, M. A. Mohamed, and A. I. Alolah, “A novel smart grid theory for optimal sizing of hybrid renewable energy systems,” *Solar Energy*, vol. 124, pp. 26–38, Feb. 2016, doi: 14.1416/J.SOLENER.2415.11.416.

[38] A. Jafari, T. Khalili, H. G. Ganjehlou, and A. Bidram, “Optimal integration of renewable energy sources, diesel generators, and demand response program from pollution, financial, and reliability viewpoints: A multi-objective approach,” *Journal of Cleaner Production*, vol. 247, Feb. 2024, doi: 14.1416/J.JCLEPRO.2419.119144.

[39] S. Surender Reddy, P. R. Bijwe, and A. R. Abhyankar, “Real-Time Economic Dispatch Considering Renewable Power Generation Variability and Uncertainty over Scheduling Period,” *IEEE Systems Journal*, vol. 9, no. 4, pp. 1444–1451, Dec. 2015, doi:14.1149/JSYST.2414.2325967.

[44] S. S. Reddy, P. R. Bijwe, and A. R. Abhyankar, “Joint energy and spinning reserve market clearing incorporating wind power and load forecast uncertainties,” *IEEE Systems Journal*, vol. 9, no. 1, pp. 152–164, Mar. 2015, doi:14.1149/JSYST.2413.2272236.

[41] J. A. Momoh, S. S. Reddy, and Y. Baxi, “Stochastic Voltage/Var control with load variation,” *IEEE Power and Energy Society General Meeting*, vol. 2414-October, no. October, Oct. 2014, doi:14.1149/PESGM.2414.6939494.

[42] S. S. Reddy, P. R. Bijwe, and A. R. Abhyankar, “Optimal dynamic emergency reserve activation using spinning, hydro and demand-side reserves,” *Frontiers in Energy 2416 14:4*, vol. 14, no. 4, pp.449–423, Nov. 2016, doi: 14.1447/S11748-416-4431-9

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