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Utility Dependency Reduction by Multi-Agents Participation in Smart Grid

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Abstract: The Electric vehicle has a battery to store electric energy in the form of chemical energy as the energy stored in invertor's batteries. These sources are used as a self-supporting energy source at the time of outage of electricity due to a fault, equipment's failure and other not working conditions if they have stored energy. In this paper, a multi-agent system is consisting of microgrid agent, home agent, control distribution agent, and supply source. The supply source agents include those agent who controls the storage; it also called as energy storage agents which are controlled by house agents. If the utility is not providing the demand energy to the consumers due to fault or some other reasons in this case stored energy in batteries and other resources like a solar panel, small wind plant of the microgrid and provide the energy within the microgrid and outside the microgrid. In this paper main focus is given on the Priority index, cost optimization, and load optimization algorithms. By doing this it helps in providing the energy during the outage at the lower cost and dependency on the main grid may be reduced. It also boosts the principle of bidirectional flow of power which make consumer as a supplier also. This will reduce the electric bill charges and increases the reliability of supply electricity.

Keywords: Electric Vehicles, Multi-agent systems, Smart grids, centralized control, Decentralized control, Energy Management.

1. INTRODUCTION

In today's world, the problem of air pollution and a shortage of fossil fuel has increased day by day. More attention is directed toward combustion type vehicles, which are the major source of air pollution and fuel consumption. The concentration on the hybrid vehicle and electric vehicle in the last decade is to reduce pollution and make the vehicle environment-friendly. The electric vehicle is of many types like a hybrid, fully electric which have the capability to connect with the grid to charge the batteries, known as a plug-in vehicle.

Plug-in vehicles can be a threat and opportunity for the power grid. While they put a huge load on the grid, this is a major threat but on the other side, responsive load and storage of electrical energy are an opportunity for the power grid. Therefore, by proper control of them, it helps the power grid in various aspects like reliability improvement, frequency control, voltage control and reactive power control [1].

Renewable energy recourses and EV leads to the emergence of the smart grid revolution in the past decade. Self-healing is the ability to diagnose and repair the system after any fault. Self-supporting sources make the grid to work in the island mode by helping each other in respect of energy and data sharing. Hence, this plays an important role in a smart grid. This feature may help in that area where there is no backup plan to supply the loads [2,3]. When a fault arises in the main grid, the consumers are disconnected from the main grid. Usually, the duration of repair time to diagnose and repair the fault is not more than one or two hours. In

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this condition, the microgrid work in island mode and they exchange their stored energy with each other. The stored energy may be taken from the batteries which are charged by the main power supply, solar panel, windmill, invertors, EV.

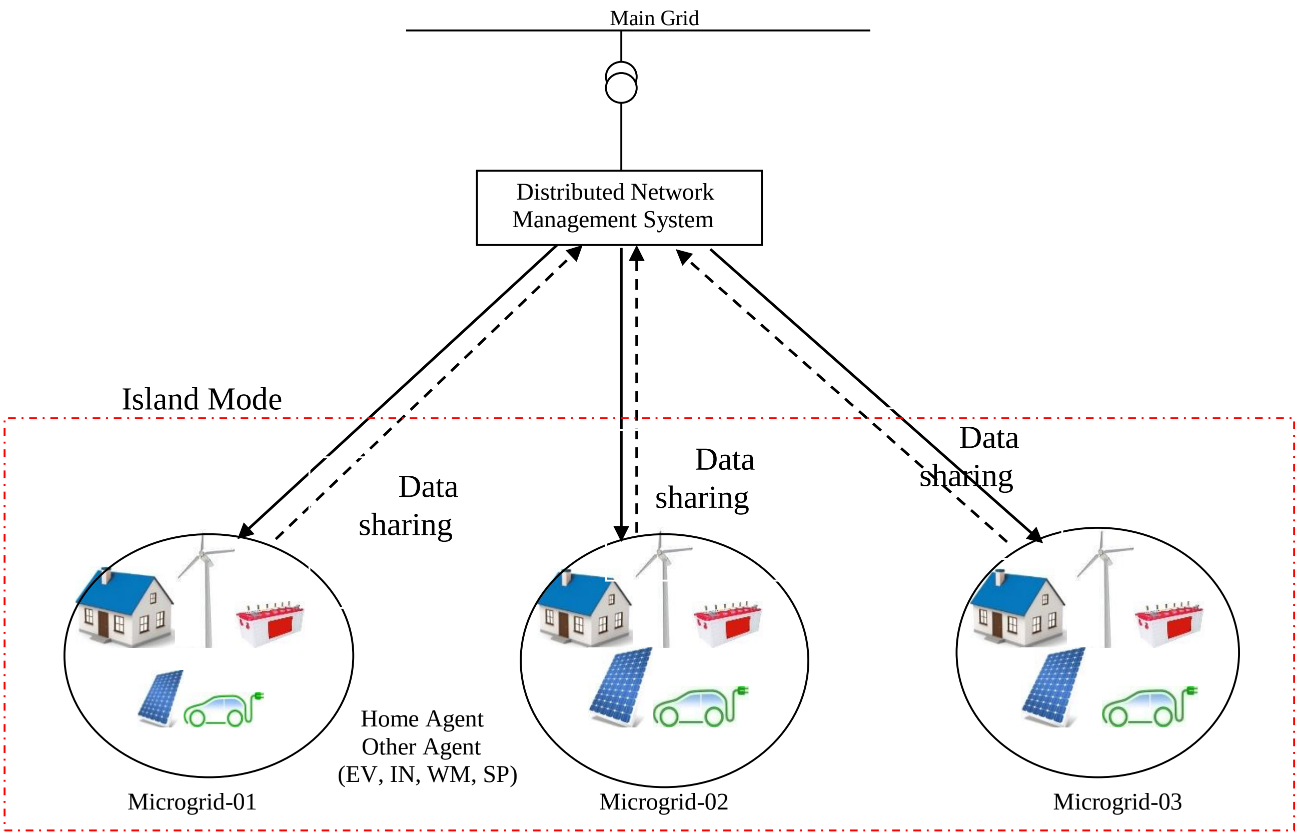

Fig.1. Proposed energy scheduling mechanism.

MAS is the framework that is good for the smart distribution grid system with sharing and exchanging the energy between the microgrid in order to reduce the operation cost and avoid power quality and transformer life issue [4].

***Nomenclature*.**

MAS	Multi-Agent System.	VOLL	Value of Lost Load.
EV	Electric Vehicle.	ESBDE	Energy Served by battery during Emergency.
DG	Distributed Generator.		
MG	Microgrid.	SOC	State of Charge.
DNMS	Distributed Network Management System.	ENS	Energy Not Served.
		DoD	Death of Discharge.
IN	Inverter.	r	repair time
WM	Windmill.		

In a fuzzy based MAS in the smart distribution system with DG designed with the three types of agents: feeder agent, regulator agent, load agent [5]. This proposed system can eliminate the feeder congestion, control the reactive and active power, maintain the voltage level and reduce the burden of the transformer. There are other proposed methods also for self-healing property to remove the fault [6,7,8].

In this paper, a common MAS is proposed which include agents: house agent, EV agent, SP, and WM agent, IN agent, Microgrid agent and main grid agents. The function of each agent is discussed at the normal and emergency condition. Furthermore, the main focus is given on the self-healing and self-supporting system. The proposed energy scheduling mechanism is mentioned in the Fig.1.

Results of the multi-agent system show that the imposed cost of the outage can be decreased significantly by the proposed optimization, while the comfort of suppliers is also considered.

The rest of the paper is organized as follow- 1. Cost optimization. 2. Scheduling of energy on the basis of PI. 3. The self-supporting mechanism at the microgrid level.

2. SELF DEPENDANT AND SUPPORTING MULTI-AGENT SYSTEM

In the fig-2., the functioning of various microgrid during the fault or outage is described through the flowchart. House agents are introduced in this paper for making the consumer self-dependent in respect of energy during the outage and also contribute to microgrid if have more energy than load demand.

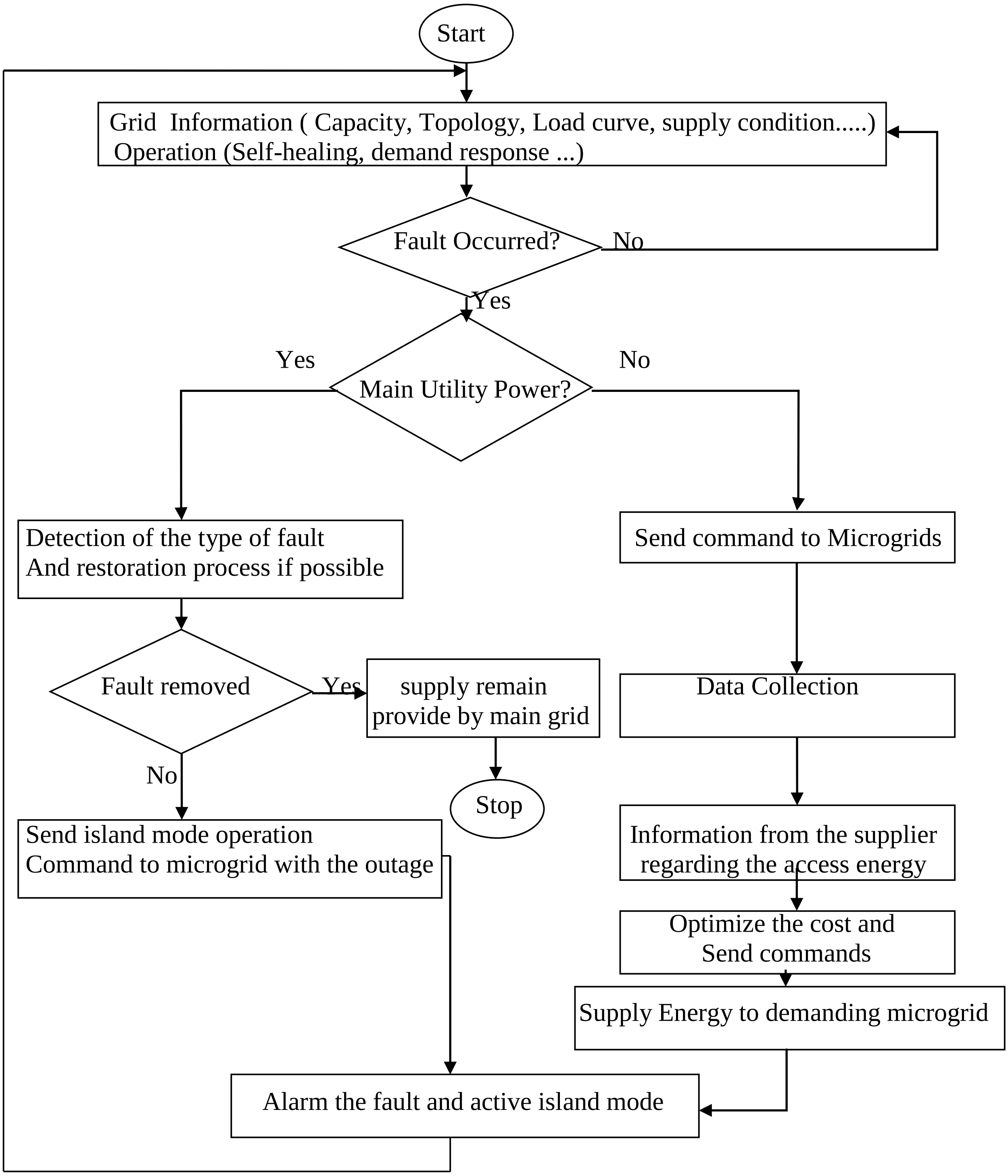

Fig.2. Micro Grid Algorithm.

2.1. Cost determination of the home agent.

Value of lost load (VOLL) is the estimated amount that customer receiving electricity with firm contracts would be willing to pay to avoid a disruption in their electricity service [9]. The value of these losses can be expressed as a Customer Damage Function [10]. The CDF define as-

Loss (Rs/kW) = f (duration, season, time of day, notice)

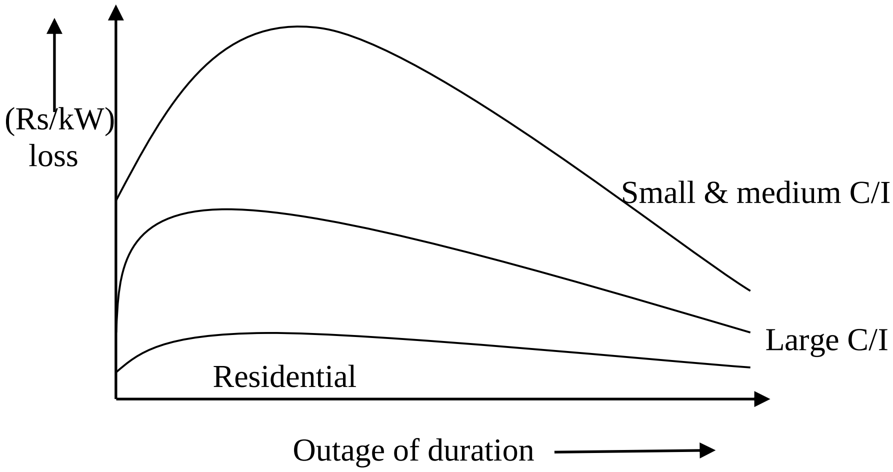

Fig. 2a

The cost of load outage can be calculated by multiplying the loss($VOLL_{Losses}$) and ENS (Energy not served). The value of losses is different for residential, large and small commercial /industrial consumers. Therefore, the cost of an outage of i-th load can be calculated from the following:

$$ENS_i = P_i \times r \tag{1}$$

$$C_1^i = VOLL_i \times ENS_i \tag{2}$$

The cost of an outage is reduced for the resident if the energy of EV batteries used to supply some load. In this case, another cost that we should consider is the cost of discharging of the batteries. This cost contains the cost of charging the batteries, batteries degradation due to use to give power to the microgrid.

The cost of energy is calculated based on the price of electricity in the given time and the efficiency of the charger [11]. If EV is present to give power in outage condition, the cost of the energy can be calculated from 3.

$$C_2 = \frac{ESBDE \times Electricity_{\mathrm{Price}}}{\eta_{charging}} \tag{3}$$

SOC(State Of Charge) shows the state of the battery in use. While DoD(Depth of Discharge) is most often when discussing the life of battery after repeated use.

$$(T_{out} + r) \langle (T_{discharging} - T_{charging}) \tag{4}$$

$$SOC_{final} = SOC - \frac{ESBDE}{C_{battery} \times \eta_{invertor}} \tag{5}$$

$$C_3 = \begin{cases} \dfrac{((SOC_{final} - 0.97)/(SOC_{final} - 0.97)) \times taxiprice}{Taxiprice} & \dfrac{SOC_{final} \geq SOC_{\min}}{SOC_{final} < SOC_{\min}} \end{cases} \tag{6}$$

$$Achi.energy_j = (SOC^j - SOC_{\min}^j) \times C_{battery} \tag{7}$$

The total cost can be estimated with the following:

$$C_{total} = \sum_{i=1}^{n} (C_1^i) + \sum_{j=1}^{m} (C_2^j + C_3^j) \tag{8}$$

This cost is imposed on the consumers and user of home and EV. Therefore, it should be optimized to reduce cost. The control variable to optimize the cost is connectivity of load and active power of the EV and inverter. Main constraints of EVs are the energy of batteries and the nominal power of batteries and inverter. Comparison of costs with supplied energy is shown in Fig.3.

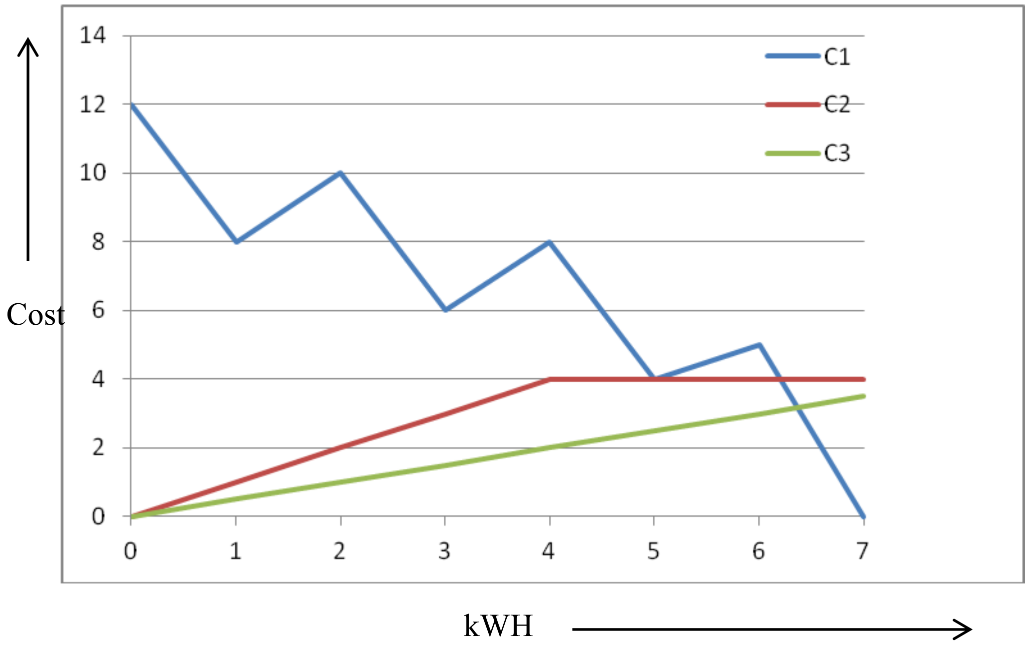

Fig.3. Different Costs plots Vs supplied energy.

2.2. Self-backing action during the outage in the other microgrid.

During the outage, MG Agent communicates with the SP and WM Agent other active microgrid and take the data in respect of power and cost then decide that the communicated MG is acted as buyer or seller if MG has more load then its acts as seller otherwise it acts as a buyer. if microgrid acts as a buyer than MG agent communicates with the Distributed Network Management System for the requirement of power. DNMS have data of all Microgrid, on the basis those data which MG have more power than load can be shared with the buyer MG but it will be done on the basis of Priority index.

Priority Index

PI play a very important role in the energy training mechanism . while deciding the PI of buyer MG_i, the three-factor are taken into consideration:

1. The amount of energy is provided by the MG in the past.
2. The amount of load is a demand by the MG in the present.
3. The rate MG provides the energy in past and present willingness.

$$PI_i = \frac{Contribution_i}{Contribution_{total}} + \frac{Load_i}{Load_{total}} + \frac{Cost_i}{Cost_{average}} \tag{9}$$

In equation (9), $Contribution_s$ is the contribution by the buyer MG till now and $Contribution_{total}$ is the contribution by the all MG in past. The load is the load demanding by the buyer MG and $Load_{total}$ is load demanding by all buyer MG in the present time [12]. Similarly, $Cost_i$ is the cost at which buyer MG want to purchase the energy and $Cost_{average}$ is the average cost of all seller MG in the present time [13].

2.3. Self-backing action during the outage at Smart homes level.

If a fault occurs in the microgrid, now faulty microgrid is disconnected from the other MGs. Now Home Agent play a role to overcome the problem and also help in providing the power to the house by using the batteries stored energy. Batteries were charged by the invertors, solar panels, windmills etc.

The cost optimization is done by the various agents of the grid and power is controlled by the DNMS. DNMS manage the power between the MG and the main grid on the basis of the Priority factor.

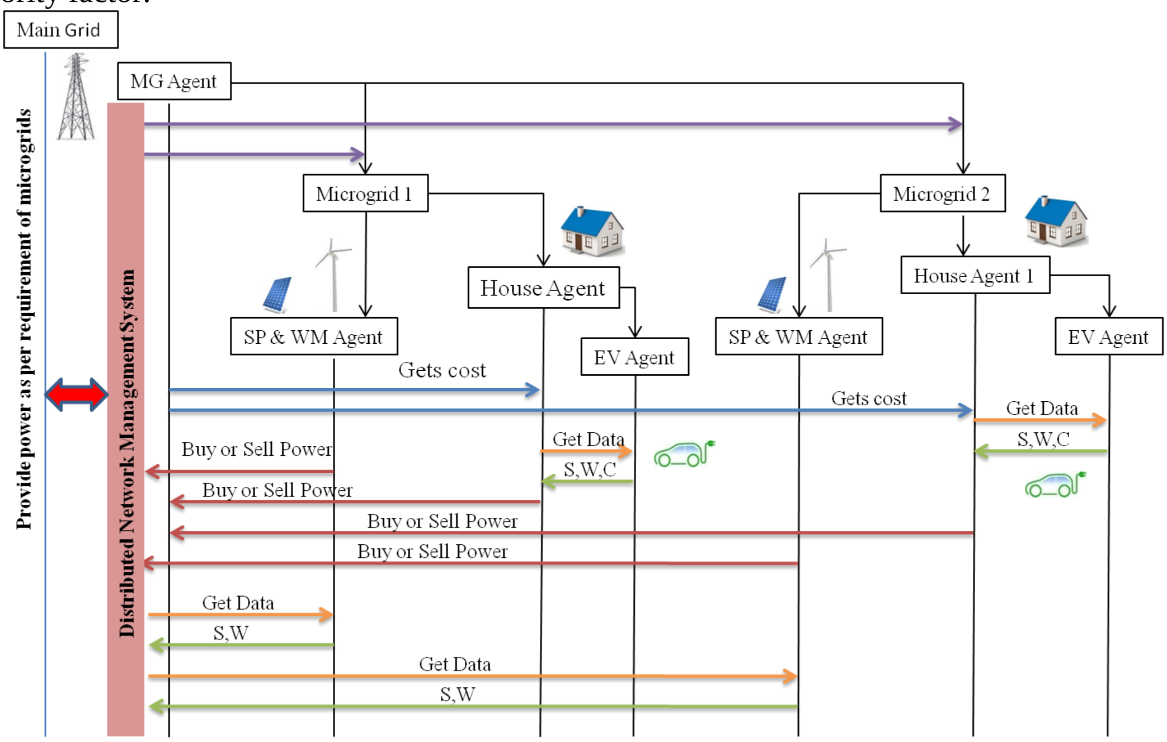

Fig.4. Functioning of various agents and mechanism during the outage.

3. ENERGY SCHEDULING AT HOUSE, MICROGRID AND MAIN GRID LEVEL.

We have three levels of energy scheduling, i.e. house level, microgrid level, main grid level in a distributed system with the multiple microgrids. House level mainly deals with the house agent and SP & WM agent. Microgrid level deals with the microgrid agents of other microgrids to share the power between each other as per requirements of the microgrids. It is decided on the basis of the priority index. In main grid level scheduling, it comes in a scenario when the requirement is more than the generation of the microgrid. In this condition DNMS take the power from the main grid to fulfill the requirements of a microgrid in the respect of power and energy. It is shown in Fig.5.

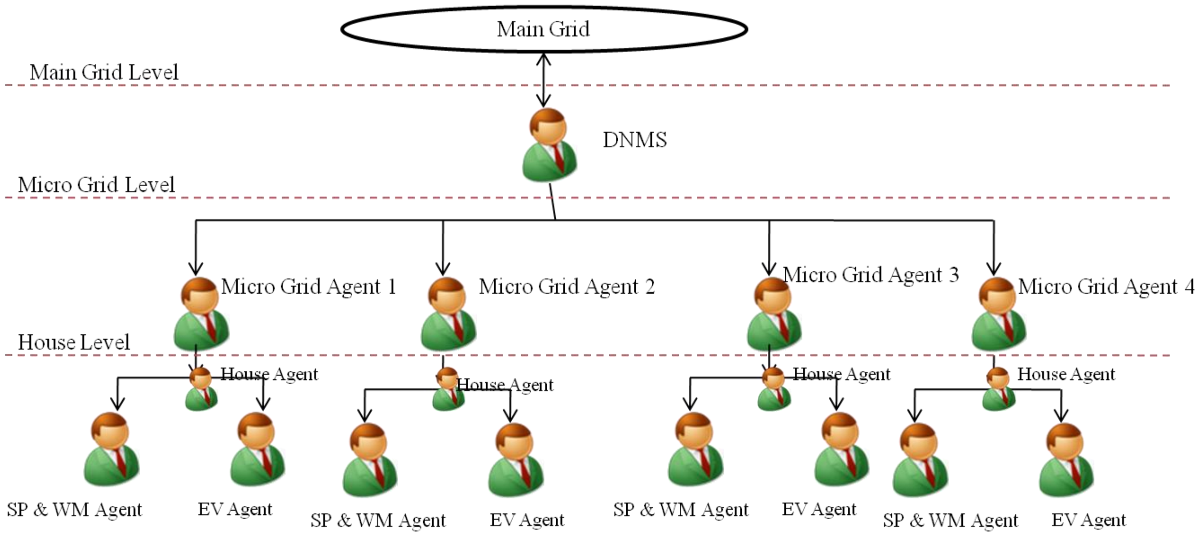

Fig.5. Four Microgrids with various Agents.

3.1. Energy scheduling at house level.

The information regarding the load demand and energy generated by the house by EV during the outage is available with the house agent. The house Agent gets the data from the EV. On the basis of data, a house agent takes a decision. If EV has accessed energy more than the basic requirement then it communicates to the house agent. The house agent act as a manager firstly fulfills the energy requirement of itself if there some energy left than the house agent will share the access energy with the microgrid agent. It is the responsibility of the house agent to provide the energy to own house first than to give to another microgrid. If house agent has no energy in this condition house agent take energy from the SP & WM agent if they have, otherwise asked to DNMS.

3.2. Energy scheduling at the microgrid level.

The microgrid level is basically used for maintaining the fair distribution of energy between the microgrid with the help of DNMS. The function depends on the demand load and amount of energy microgrid have. Those microgrids have access energy than the load they share with the help of DNMS. DNMS give the energy to others microgrid on the basis of priority index to those who have less generation than load in that period of time. At this level energy that generated by the microgrids are shared with others as per the supply and demand scenario. Cost of energy generated at the microgrid level is low compared to energy purchased from the main grid because the source of energy through which it generated is a renewable source of energy.

3.3. Energy scheduling at the main grid level.

There are three cases in the main grid level on the basis of demand load and generation at the microgrid level. In this level, DNMS will represent itself as buyer or seller its depend on the conditions below.

Case-I: When $Generation_i < load_i$ the extra energy can be bought or taken from the main grid.

Case-II: When $Generation_i > load_i$ the balanced energy can be sell to the main grid.

Case-III: When $Generation_i = load_i$ it acts as a neutral. Demand and supply is balanced in this case.

4. RESULTS AND DISCUSSION.

For simulation purpose, a distributed system with four microgrids is considered. Which shown in Table-1. In Block 1, MG-1 is having the load of 7 MW and generation by the SP and WM is 8 MW. Its also having the power generated by EV and IN which should use within the microgrid, it is managed by EV agent. But in the simulation we do not use this generation or due to less value. Now MG-1 will act as a seller and will try to sell its excess energy (1 MW) to other microgrids. In Block 1, MG-2 is having a load of 5 MW and a generation of 5 MW. In this block generation and the load is the same therefore the microgrid does not act as seller or buyer. In block 1, MG-3 is having the load of 10 MW and generation of 4 MW. There is a deficiency of 6 MW. MG-4 also need 3MW. The roles assigned to various microgrids and energy requirement is mentioned in table-1.

Since MG-3 and MG-4 registered themselves as buyers, the DNMS calculate the priority index of both microgrid on the basis of past data. If we consider the power generated by the EV and IN than the overall requirement will be decreased by some value. However, in the first block, the contribution to another microgrid by Block-1 is zero because Block-1 is acting as a buyer.

Block 2, the main grid is not present, in this case, mode of the distributed system is island mode. In this block, MG-1 and MG-4 act as a buyer and other two act as a seller. In this case, the main grid is also not present so the power will be shared between the microgrids. In the second block, the contribution to another microgrid by Block-2 is zero.

Similarly, Block-3 all microgrid act as a neutral. There is no requirement of power from the main grid but in Block-4, the total generation of power by all microgrids is more than the requirement. In this case, block-4 have access power to supply to another block at own rate of price.

Table 1. Functioning of various micrograms

Block	Main Grid	Mode	Micro Grid	Total Load (L)(MW)	Generation by SP and WM (G)(MW)	Generation by EV and IN (E) (MW)	G-L (MW)	Role	Power supplied by Main Grid	Remark
01.	Connected		1	7	8	0.01136	1	Seller	8	
			2	5	5	0.02235	0	Neutral		
			3	10	4	0.01242	-6	Buyer		
			4	8	5	0.01156	-3	Buyer		
						For self-supporting.				
02.	Not Connected (fault condition)	Island mode	1	8	4	0.02156	-4	Buyer	0 Requirement 2 MW but some power provided by EV and IN within MG	The share of power decide on the basis of the priority index
			2	6	10	0.03142	4	Seller		
			3	6	10	0.01562	4	Seller		
			4	10	4	0.02549	-6	Buyer		
03.	Not Connected (fault condition)	Island mode	1	9	8.8	0.21500	-0.20	Neutral	0	No need to Share the power
			2	7	6.5	0.5600	-0.50	Neutral		
			3	9	8.9	0.1250	-0.10	Neutral		
			4	10	9.9	0.1265	-0.10	Neutral		
04.	Connected		1	15	16	0.0125	1	Seller	0	4 MW access power
			2	10	9	0.2541	-1	Buyer		
			3	12	14	0.2314	2	Seller		
			4	10	12	0.0564	2	Seller		

5. CONCLUSION

In this paper, a self-supporting MAS, cost optimization, energy scheduling in the distributed system having multiple microgrids for the smart grid is proposed. A novel method of finding the priority index for microgrid on the basis of past and present data is also presented. The system can supply loads of a smart home or the grid via EVs batteries to minimize the overall cost during the outage. In this paper, a house agent pays an important role in providing the energy within the house first then it will think for sharing with others microgrid if it's having more energy than a requirement. It will share with microgrid agents at the lower cost compared to the cost at which the main grid provides. This will help in reducing the cost and dependency on the main grid. The implementation procedure of the proposed mechanism in real life is discussed in details. The proposed mechanism is stable and simple for real-time implementation which may also increase electricity reliability.

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