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AN HYBRID TECHNOLOGY IN DISTRIBUTED GENERATION FOR HOUSEHOLD DEMAND WITH STORAGE CAPACITY

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Abstact— In ***Future Decentralized Power Generation will be the most important one in the Electricity Generation System. Who are prepared to invest in Generation-Battery Systems and Employ Energy Management Systems in order to cut down on their Electricity Bills. The main objective of this paper is to determine the Optimum Capacity of a customer's Distributed-Generation System and Battery within the Framework of a Smart Grid. The proposed approach involves Developing an Electricity Management System based on Stochastic Variables such as Wind Speed, Electricity Rates, and Load. In a Residential Distribution Grid of so that effects of Electricity Rates as well Wind and Photo Voltaic Generation and Electricity Storage Costs on Optimum Capacities of a Battery for a Smart Home. the Hybrid Genetic Algorithm and Particle Swarm Optimization technique to Develop the Electricity Management System.***

Keywords— Genetic Algorithm, Particle Swarm Optimization.

I. INTRODUCTION

1.1 Renewable Energy

Renewable energy production has been steadily increasing as international goals to reduce dependence on fossil fuels have been on the agenda for nations worldwide. Solar photovoltaic (PV) power systems are becoming a prevalent renewable energy option with the cost of PV cells decreasing and their solar conversion efficiency increasing. Yearly growth rates over the last five years were on average more than 40% with a worldwide production of 7.3 GW making photovoltaic one of the fastest growing industries.

1.2 Power generation

Renewable energy provides 21.7% of electricity generation worldwide as of 2013. Renewable power generators are spread across many countries and wind power alone already provides a significant share of electricity in some areas.

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1.4 Wind power

Airflows can be used to run wind turbines. Modern utility scale wind turbines range from around 600 kW to 5 MW of rated power although turbines with rated output of 1.5 to3 MW have become the most common for commercial use the power available from the wind is a function of the cube of the wind speed so as wind speed increases, power output increases up to the maximum output for the particular turbine. Areas where winds are stronger and more constant such as offshore and high altitude sites are preferred locations for wind farms. Typical capacity factors are 20-40% with values at the upper end of the range in particularly favorable sites .Globally the long-term technical potential of wind energy is believed to be five times total current global energy production 40 times current electricity demand assuming all practical barriers needed were overcome. This would require wind turbines to be installed over large areas particularly in areas of higher wind resources such as offshore. As offshore wind speeds average 90% greater than that of land so offshore resources can contribute substantially more energy than land stationed turbines.

1.5 Solar Power

Solar energy radiant light and heat from the sun is harnessed using a range of ever evolving technologies such as solar heating photovoltaic concentrated solar power solar architecture and artificial photosynthesis. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture convert and distribute solar energy. Passive solar techniques include orienting a building

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to the Sun selecting materials with favorable thermal mass or light dispersing properties and designing spaces that naturally circulate air .Active solar technologies encompass solar thermal energy using solar collectors for heating, and solar power converting sunlight into electricity either directly using photovoltaic or indirectly using concentrated solar power.

II. PROPOSED METHODOLOGY

The main objective of proposed method is to develop an appropriate method for determining the optimum capacities of battery storage and renewable generation such as a wind turbine of a smart household with an electricity management system that minimizes the overall electricity cost of the household.

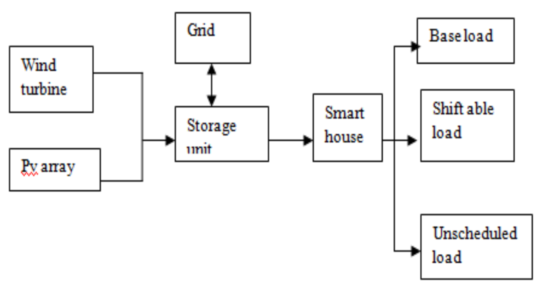

Fig 1 : block diagram

A wind turbine is a device that converts kinetic energy from the wind into electrical power .The grid may be an electricity line which transmits and distributes the energy to consumer sectors for 24 hrs.

Photovoltaic power generation systems use the rays of the sun as a source of electric power. Accordingly the amount of power generated is strongly influenced by the weather conditions that determine how much sunlight gets through. The power output of a photovoltaic panel is normally rated based on a solar radiation intensity of falling on a panel at a temperature of 25°C. Because the angle of incidence of sunlight varies depending on the season and the time of day the power generated from a panel on a fixed platform typically starts to increase from dawn peaks when the sun reaches its zenith for the day and then decreases again toward sunset. Hence maximum time duration is 8hrs.The load is divided into three type namely base load shiftable load and unscheduled load. Base load consists of end use devices whose power usage is predetermined and non reschedulable such as refrigerators and most lighting. The shiftable loads are shiftable in time and susceptible to delay Washers dryers and dishwashers are often among the loads which can be delayed but the task should be accomplished by a certain deadline. Air conditioners and water heaters may be assigned to either one of the first two categories according to customer preferences and level of comfort desired.

The unscheduled loads are which may be plugged in without any predetermined plan such as hair dryers and electric drills. Overall consumption of a house hold is determined in hourly basis.

Wind turbine and PV generates power and is measured in hourly or daily basis. The generated power is stored in a storage battery and distributed to the consumer end according to the consumption of a house hold based on load. First if it is insufficient the difference power is purchased from grid which may be charged on the basis of Electricity Purchase Rate .The excessive power enerated by the wind turbine or PV after the utilization of the house hold can be sold out on the basis of ESR. By calculating the electricity generation and utilization the power consumed by the small house hold system is determined using hybrid.

2.1 Optimization model

As described before obtaining the optimum capacity for the renewable generator and the battery is a planning problem which should include the behaviour of the smart home in the optimization process. Operation of a smart home in the long run is simulated by providing load generation and electricity rates at each hour of the day

as inputs to the HEMS .The electricity cost of the home for the time interval of the day can be calculated by

Step1: The duration of each interval is one hour in this study.The electricity cost of the home for the time interval of the day can be calculated by the following equation.

$$CH(\Delta t_j)=C_G.E_G(\Delta t_j)+C_B.C_{apB}.\Delta t_j+E_{Buy}(\Delta t_j)\times EPR(\Delta t_j)-E_{Sell}(\Delta t_j)\times ESR(\Delta t_j) \quad (1)$$

Where $E_{Buy}(\Delta t_j)$ represent the amount of electricity bought from the grid during time period Δt_j. $E_{Sell}(\Delta t_j)$ represent the amount of electricity sold to the grid during time period Δt_j

A simple model representing the power curve of the wind turbine is employed to obtain the output power of the wind generation based on wind speed. Equation (2) is used to derive .The output energy represented by E_G of the wind turbine for each hour j is calculated by

$$E_G(\Delta t_j)=\begin{cases} C_{apG}\dfrac{(V_W(\Delta t_j)-V_{ci})}{V_r-V_{ci}}\Delta t & V_{ci}\le V_W(\Delta t_j)\le V_r \\ C_{apG}.\Delta t & V_r\le V_W(\Delta t_j)\le V_{co} \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

Where V_{ci} is cut in speed where wind turbine starts to generate V_{co} is cut off speed where wind turbine stops generating V_r is rated speed V_w is wind speed.

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There are cost benefit tradeoffs involved in optimum capacity calculations. Higher capacity generators are costlier but contribute more to supplying load and reducing dependency on grid power. The surplus generation can also be sold back to the grid. In the same way paying more for a higher capacity battery could be compensated for by more surplus energy storage and energy trade capability. Therefore the objective function to be minimized is the total electricity cost of the household calculated by.

$$F = \sum_{j=1}^{N} C_H\ (\Delta t_j) \qquad (3)$$

The power flow constraint is determined for any duration is calculated by

$$\delta\ (\Delta t_j)=E_{Buy}(\Delta t_j)-E_{sell}(\Delta t_j)-E_B(\Delta t_j) \qquad (4)$$

There are also some inequality constraints to comply with the operational limits of the battery as mentioned and power transfer limits defined by

$$\begin{cases} E_{Sell}(\Delta t_j)< E_{Sell,max} \\ E_B(\Delta t_j)<R_C\times\Delta t \\ -\ E_B(\Delta t_j)<DOD\times\ C_{apB} \\ B(\Delta t_j)< C_{apB} \end{cases} \qquad (5)$$

2.2 MCS-PSO Process

Since the electricity cost of the home depends on HEMS and the inputs to the HEMS are stochastic variables obtained from their probability distributions this cost can be generally represented by an implicit function of the following variables and parameters.The cost can be determined by

$$C_H=f(L_1,L_2,L_3,V_W,B_{init},ESR,EPR,C_G,C_B,C_{apG},C_{apB}) \quad (6)$$

PSO is used to calculate the optimum CapG and CapB by minimizing an objective function. The objective function of the HEMS is to minimize the total expected electricity cost of the household calculated by MCS over the duration of the study. In the PSO method initial capacities for the generation and battery are selected; and then a population of M particles is generated to evolve toward the optimum capacities of battery and wind generation for the household. This method has been demonstrated to be more robust and faster in finding the global solution compared with other heuristic optimization methods such as genetic algorithms.

To improve the efficiency of the optimization process an iterative procedure combining MCS and PSO methods is proposed. Using the hybrid MCS-PSO method the input to each iteration of the PSO is stochastic and originates from the variables probability distribution functions. Therefore in the long run it inherently incorporates the MCS method while it is searching for the optimum solution. The procedure can be expressed by the following steps.

Step2: Determine N individual probability distribution functions for different variables such as wind speed load and electricity rate according to historical data. Each function represents the probability distribution of a variable for a time step Δtj of in the MCS-PSO

Step3: ObtainC_B,C_G and the parameters of the MCS-PSO method such as stop criterion based on maximum number of iterations or minimum error and the number of particles M in the PSO.

Initialize each particle by assigning two dimensional position and velocity vectors according to (7), and also initialize X_{gbest} and the battery charge B^i_{init} (K) for the iteration K=1.Initialization of each particle is assigned by

$$\begin{cases} X^i(k)=[C_{ap}{}^i{}_G(k) \quad C_{ap}{}^i{}_B(k)] \\ V^i(k)=[v^i_{CapG}(k) \quad v^i_{CapB}(k)] \end{cases} \qquad (7)$$

Step4: For iteration k and every particle of the population given the current $C_{ap}{}^i{}_G(k)$ and $C_{ap}{}^i{}_B(k)$. do the following Calculate the values of the loads, ESP and EPR. Their N distinct probability distribution functions.

Step5: Run the HEMS process for duration of $T=N.\Delta t_j$ and compute the value of the fitness function Fitness function is determined by

$$F(x^i(k))= \sum_{j=i}^{N} C^i{}_H(k,\Delta t_j) \qquad (8)$$

Step6: If $F(x_i(k)<F(x_{pbest})$ then update the values for the local optimum capacities $x_{pbest}=x^i(k)$ and if $F(x^i(k))<(x_{gbest})$ hen update the global best capacities $x_{gbest}=x^i(k)$.

$$\begin{cases} X^i(k+1)=x^i(k)+v^i(k+1) \\ v^i(k+1)=w(k).v^i(k)+c_1\square_1(x^i_{pbest}-x^i(k))+c_2\square_2(x_{gbest}-x^i(k)) \\ B^i_{init}(k+1)=B^i(k,\Delta t_N) \end{cases} \qquad (9)$$

Step7: Determine the optimum capacities associated with the minimum objective function.

$$\begin{cases} [C_{ap}{*}_G C_{ap}{*}_B]=x_{gbest} \\ M_{in}\{C_H(T)\}=F(X_{gbest}) \end{cases} \qquad (10)$$

2.4 Hybrid PSO with GA

The basis behind this is that such a hybrid approach is expected to have merits of PSO with those of GA. One advantage of PSO over GA is its algorithmic simplicity.

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Another clear difference between PSO and GA is the ability to control convergence. Crossover and mutation rates can subtly affect the convergence of GA. but these cannot be analogous to the level of control achieved through manipulating of the inertia weight. In fact the decrease of inertia weight dramatically increases the swarm's convergence. The main problem with PSO is that it prematurely converges to stable point which is not necessarily maximum. To prevent the occurrence position update of the global best particles is changed. The position update is done through some hybrid mechanism of GA. The idea behind GA is due to its genetic operators crossover and mutation. By applying crossover operation information can be swapped between two particles to have the ability to fly to the new search area.

The purpose of applying mutation to PSO is to increase the diversity of the population and the ability to have the PSO to avoid the local maxima. Each particle tries to modify its position using the following information

- The distance between the current position and pbest .Each particle knows its best value so far pbest
- The distance between the current position and gbest each particle knows the best value so far in the group gbest among pbests.Here particle represents the capacity in kW.

III. RESULTS AND DISCUSSION

The previously described MCS-PSO method has been applied to the case study. The total number of simulation iterations was 10 000 which ensured the convergence of the simulation. The cognitive and social parameters of the PSO method were selected to be 2.5 and 1.5 respectively the population of the particles was 20 the problem space was bounded by the maximum capacities of 15 kW for the wind generator and 15 kWh for the battery and the maximum velocity of the particles was limited to 20 percent of the maximum capacities of the wind generator and the battery. The definition of the parameters of the PSO method can be found .Proper behavior of the proposed method was captured through sensitivity analysis to a number of input parameters. The following case studies have been defined to demonstrate the results of the proposed method.

3.1 Sensitivity To Both ∆R And Esellmax

In this case, the effect of both∆R and E_{Sell}max on the optimum capacities of a wind generator and battery is studied. The optimal surface of the battery capacity with different storage and wind generation costs. As decreases.The optimum point is shifted toward higher battery capacities. In addition as the cost of wind generation increases larger batteries become relatively more efficient than wind generators It is observed that the optimization process prefers to choose the highest battery capacity when the battery cost is at its minimum and the wind generation cost is at its maximum value. Similarly shows the effect of levelized costs of generation and battery on optimum capacity of the wind turbine. The cost of a battery does not have a considerable effect on the generator capacity. On the other hand as the cost of generation decreases higher capacity wind turbines become more beneficial. In this graph the generation cost of about 3.5 cents/kWh acts like a turning point at which there is a high slope toward higher wind generation capacities. This is because as mentioned earlier the average EPR of this case study is 3.2cents/kWh and therefore generation costs less than this rate become exceedingly appealing. As a result of the optimization process the minimum household electricity costs are computed and plotted.

As expected the electricity cost of the home is highest when both and are at their maximum values. An interesting result is achieved by comparing the electricity cost in this figure with one of a conventional home without a generation-storage system. In the case of a conventional home the electricity cost is 92 cents/day which is close to the value of the smart home with a of 5 cents/kWh and a of 0.6 cents/kWh per hour. Therefore we expect that beyond this operating point no additional savings can be achieved by investing in a wind generator and battery, indicating the corresponding optimum capacity of the wind generator and battery should be almost zero.

3.2 Sensitivity to EPR

In this case the sensitivity of the capacities and electricity cost of the home for the base case with different electricity rates have been studied and the results are plotted based on shape preserving interpolation In lab view. EPR is increasing an increasing trend toward higher generation-battery capacities is observable. In this case when EPR decreases toward 2.5 cents/kWh, there is less incentive to invest in high capacity wind generators and batteries because as depicted in the bottom the minimized electricity costs of the smart home and the conventional home get closer. It is notable that as the electricity cost of a conventional home raises with a higher EPR the electricity cost of the smart home decreases. The difference between these two costs is more noticeable.

At electricity rates higher than the levelized cost of wind generation where the electricity cost of the smart home has a higher rate of decrease. Homes are even able to make a profit from selling their power to the grid at an average EPR of 5 cents/ kWh because beyond this point the cost of wind generation becomes less than the average ESR. This is achieved as a result of proper utilization of the wind turbine and the battery system

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3.3 EPR and ESP

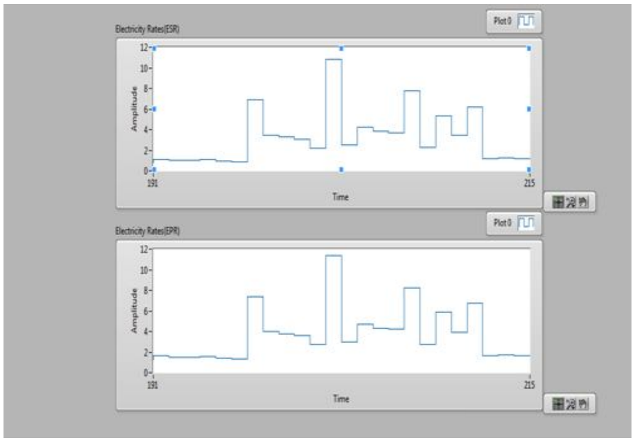

Fig2 : Output Result

IV. CONCLUSION

The method described can help residential customers and small business owners decide on investing in the right amount of renewable generation and battery capacities that are optimized according to their load profile renewable resource availability and electricity rates. Results also indicate that given the levelized costs of a wind generation and battery storage system an average electricity rate may exist at which investing in these systems will no longer be beneficial. Sensitivity analyses were conducted to investigate the effects of electricity rates as well as wind generation and electricity storage costs on optimum capacities of a wind turbine and battery for a smart home. The results show how the customer could benefit from higher capacities of wind generation and battery as their associated costs drop. It was also illustrated that if certain conditions are met in the system the smart grid customer has an opportunity to make proper investments and profit from selling generation back to the grid as well.

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