A GENETIC ALGORITHM APPROACH TO OPTIMIZE DISPATCHING FOR A MICROGRID ENERGY SYSTEM WITH RENEWABLE ENERGY SOURCES

Sajib Sen[1], Kishor Datta Gupta[1], Subash Poudyal[1] and Md Manjurul Ahsan[2]

[1]Department of Computer Engineering, University of Memphis, USA
[2]Department of Industrial Engineering, Lamar University, USA

ABSTRACT

Distributed network reconfiguration techniques are used widely to optimize power distribution systems. As renewable energy generation are very stochastic in nature, network reconfiguration with this stochastic nature does not provide the optimal solution. To address this problem a three-objective genetic algorithm approach has been taken in this project to find the optimal solution of energy scheduling throughout a day, simultaneously using the concept of network reconfiguration. In this research paper, we have applied a genetic algorithm approach, in order to optimize dispatching power with reconfiguring the network and scheduling the power sources. Our proposed methods shows that, it is possible to get 1MW less line lose compared to general condition.

KEYWORDS

Micro grid, Genetic algorithm, Power distribution, Network reconfiguration.

1. INTRODUCTION

Maintaining green and reliable power system, hybrid energy system gaining popularity day by day. This system is still not available commercially though it has been recognized for its several benefits a decade ago. Minimizing fuel cost, maintaining the operator's demand, minimizing transaction cost where power can be transferred, satisfying load demand, switching from grid connected to island mode, protection issues and power quality- these problems hindering micro grid system to become commercially available. As we are running out of our fuel and because of global warming, conventional power systems are discouraged nowadays to implement in any form, especially in island mode. We have many available renewable energy sources to implement in island mode as well as to replace the conventional system also. But because of the stated above barriers, it is still not available to the consumer premises which can provide the robust energy management system with conventional grid incorporating high penetration of renewable energy sources and in stand-alone mode also.

Besides integrating renewable sources modern societies are also interested to integrate all generating plant, DC and AC transmission line as well as a distribution system. But the power loss associated with the generation, transmission and distribution are calculated as 8-15% [1]. Integrating renewable

Natarajan Meghanathan et al. (Eds) : CSTY, AI, MaVaS, SIGI, FUZZY - 2019
pp. 01-09, 2019. © CS & IT-CSCP 2019 DOI: 10.5121/csit.2019.91401

source can reduce the generation cost. But to find the best service from these energies we need optimal power network which will ensure reduced losses related to transmission and distribution.

"Genetic algorithm (GA) is a meta heuristic motivated by the rule of natural selection that applies to the more general class of evolutionary algorithms (EA). Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on bio-inspired operators such as mutation, crossover, and selection"[11]. Genetic algorithm nowadays used for lots of applications such as image processing[14], security[12] even in content review [13] and we showed that it can implement in smart grid.

2. RELATED WORKS

An alternative solution to reduce this power loss in the distribution system is reconfiguring the power network [2]. But this is one of the most computationally complex problems as it needs to optimize several objective functions like as demand-supply, power losses, voltage drop limits, and radial network. To deal with this complexity new algorithms are emerging gradually.

Moreover, different meta heuristic algorithm for solving the Distributed System Reconfiguration (DSR) problem using multi-objective optimization approach became very popular nowadays [3-8]. A related literature review is given in [9][12]. In such optimization technique, several objective functionsare optimized simultaneously, like as minimizing line loss, satisfying demand with fewer sources involved etc. Practically, most of the time it is impossible to find a single solution as most of the objectives functions are conflicting to each other. In this regards a set of the solution, known as a Pareto-optimal solution, has been obtained which represents a trade-off between all objective functions. In the last decade, evolutionary algorithms particularly for obtaining Pareto-optimal solutions for DSR problems have been used largely [10]. Most of the work was related to optimizing distribution network. But as renewable energy sources have stochastic nature in generating power, to integrate renewable sources effectively optimization in the source network is also needed. So, in this paper our main contributions are: (1) an encoding scheme of dispatching energy satisfying demand constraint and source constraint had been proposed (2) an encoding scheme of network configuration to optimize radial configuration had been proposed (2) a Pareto-optimal solution for dispatching renewable energy with maintaining all network constraint, demand supply and minimizing line loss had been proposed.

3. PROBLEM STATEMENT

In general, Distributed System Reconfiguration(DSR) problem consists in generating new topology that satisfies different objective functions. Though in normal distribution system operation efficiency and minimizing line loss are the main concern, but in this report three objectives have been considered: (1) minimizing power losses with maintaining radial configuration, (2) satisfying demand response, (3) satisfying most of the demand by the source which has least generation cost.
In our methodology, we used three renewable energy sources, which are hydro-electric power, wind energy power, and solar power and we choose a load network having 16-line sections, 13 loads connecting with a bus bar and three energy sources.

4. PROPOSED GENETIC ALGORITHM

We proposed a multi objective genetic algorithm method having a tournament selection method, single point crossover and 0.1 to 0.01 mutation rate.

Our first objective fulfilled by maintaining the power network acyclic with removing a certain number of edges. The second objective obtained by giving a penalty to those genes which have less supply power than demand. For the third objective, we designed a fitness function and awarded the fitness containing such a gene. Here we have used a nested GA concept, where every individual gene of chromosomes independently performs another GA..

A. Algorithm

Step 1: Initialize a population of size **N**
    for each population Initialize chromosome of size **M**=24 [24 for hours from 1 AM to 12 AM]
        for every chromosome initialize two types of genes: [2 types for 2 objectives]
            Initialize genes for sources of size 3(3 bit) [for optimizing energy sources]
            Initialize genes for the **fittest network ()** of size 14 [for network optimization]
        for every chromosome calculate chromosome fitness based on fittest from both genes
Step 2:
    For **G** number of generation
        Evolve **N** population through Crossover & Mutation
Step 3: Output the fittest chromosome

The procedure of fittest network ():

Initialize a population of power network of size **P** of Graph G = (V, E)
Initialize chromosome of size **Q** [Here 14] by **check ()**
For **R** number of generation evolve population through crossover and mutation
Output: Fittest network after R generation end

The procedure of check ():

1 Generate a **Q** number of genes of size 1 (Random number from 1 to 16) by randomly deleting two edges and checking Strong Connectivity through remaining edges. [Applied DFS to check strongly connectivity]
If not Strongly connected, repeat 1
Otherwise, output the network.
end
V= nodes of the load
E= Line section between loads
P= # of Population of power network g =(V+E)
R=# of generation to evolve the power network g =(V+E)
M= 24 # of genes having fittest power network and optimized energy sources
from R generation
N= # of M population
G= # of generation to evolve N population

B. Encoding Scheme

As in our project, we are using three energy sources and our target is to optimize the energy sources scheduling for 24 hours, our chromosome size is 24, each for every hour. To represent the assignment of energy sources an encoding of 3 bit, where each bit represents each energy sources, has been taken. A sample example is given below:

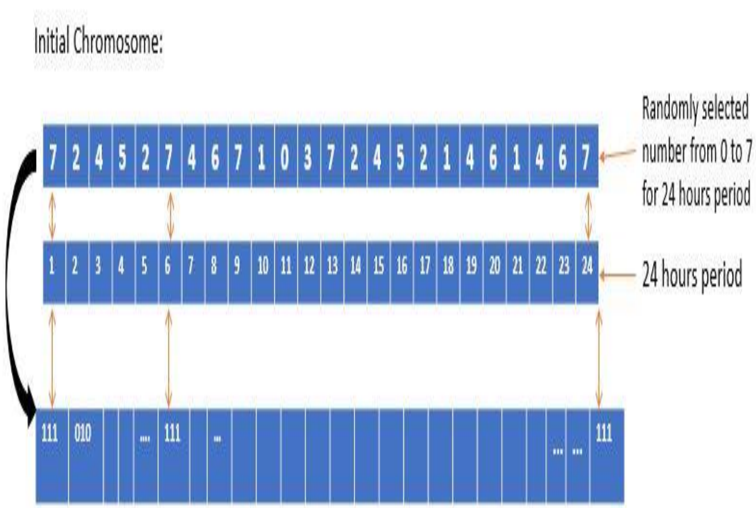

Fig. 1. Encoding scheme

Hydro	Wind	Solar	Hours	Load Demand
2100	2407	0	1	2200
2150	2411	0	2	1100
2180	2200	0	3	1050
2180	2102	0	4	1040
2000	2028	0	5	1100
2200	1934	0	6	2300
3960	1660	0	7	3400
4450	1337	323	8	3500
3090	1044	2218	9	3510
2860	854	3988	10	3530
2810	822	4749	11	3530
2660	717	5294	12	3520
2630	558	5663	13	3510
2700	488	5896	14	3500
3070	376	5780	15	3490
2900	332	5431	16	3500
4420	252	3456	17	4540
4880	231	751	18	4600
4870	244	0	19	4570
4900	341	0	20	4550
4530	418	0	21	4490
4220	474	0	22	4300
3740	626	0	23	4250
3640	740	0	24	4200

Fig. 2. Sample hourly breakdown of energy sources and load demand [11]

In the diagram below (111) gene is randomly taken for t=6 hours, which represent total $\sum_{j=1}^{n} P_{Tj}$ = 2200+1934+0= 4.134 MW energy supplied by the three sources in that hour where corresponding demand is 3.4MW.

Fig. 3. Encoding scheme breakdown

Encoding Scheme (Genes for Fittest Network): Sample network

A network with 3 power sources, a bus bar, 16-line section and 13 loads had been taken for this project. Assume the network is specified as shown in figure below. First network has 13-line section and 3-line section are randomly chosen to remove. 16-line section with 13 loads make cycle here. As our purpose is to make radial configuration, removing certain number of line section with no cycle make the network acyclic as well as reduces the line loss.

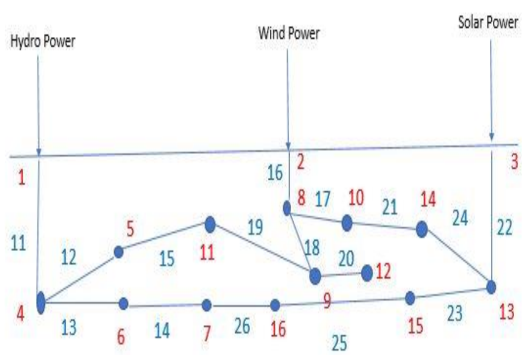

Fig. 4. The encoding scheme for genes for fittest network

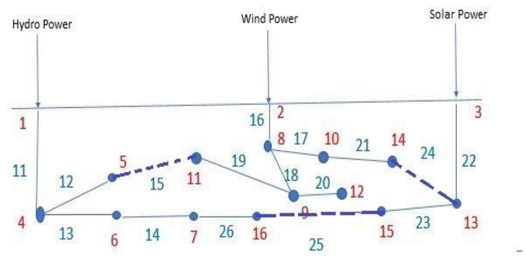

Fig. 5. Red numbers are nodes, Blue solid/dashed lines are line section active/opened, Blue numbers are line section number

C. Fitness Functions

The objective function for minimizing power losses with maintaining radial network is:
$\sum_{i=1}^{R} \min(f_L)$; R is the number of generation occurred for network reconfiguration

$Loss\ function,\ f_L = P_{Loss} = \sum_{i \in Ni} I_j^{\,2} R_i$

where $I_j = \frac{P_j}{V} = \frac{P_j}{220kV}$, $j = 1,2$ *and* 3 *and* $N_i =$ *number of nodes*

$V_{\min} < V_j < V_{max}$

The objective function for satisfying demand response is:

$$penalized\ function,\ f_D = \begin{cases} 1, & if\, D_t < \sum_{j=1}^{n} P_{Tj} \\ & 0,\ otherwise \end{cases}$$

Here $\sum_{j=1}^{n} P_{Tj}$ is the total sum of all individual energy sources active during that period. If the supplied power satisfies the demand of that period (such as 10AM- 11AM) then $f_D = 1$ otherwise zero.

Objectives function for satisfying demand by the source which has least generation cost is:
If Hydropower$P_{T1} > D_i$ and $P_{T2} = 0$ and$P_{T3} = 0$ [To use Hydro-electric power most]
f_H =0.001 [Award]

If Hydro power & Wind power $P_{T1} + P_{T2} > D_i$ and $P_{T3} = 0$& Hydro power $P_{T1} < D_i$
f_{HW} =0.001 [Award]

Here D_i is the demand of that hour. f_H is the fitness function for hydro power uses and f_{HW} is the fitness function of hydro and wind power use.

D. Total Fitness

Individual gene fitness $f_i = f_D * f_H * f_{HW} * f_L$
Total chromosome fitness = $\sum_{i=1}^{24} Fi$

E. Selection Scheme

We have used the tournament selection method. For first GA we used the n/2 size of tournament population winner for crossover operation. For nested or second GA we also used the n/2 size of tournament population for crossover operation.

F. Crossover & Mutation

We used single point crossover for both GA. We took one elite chromosome as unchanged and for the n-1population, we made a crossover in two fittest winners from tournament selection. A sample example is given:

Crossover Operation between network configuration:

Crossover is taken in such a way that after crossover the resulting individual maintains the radial configuration.

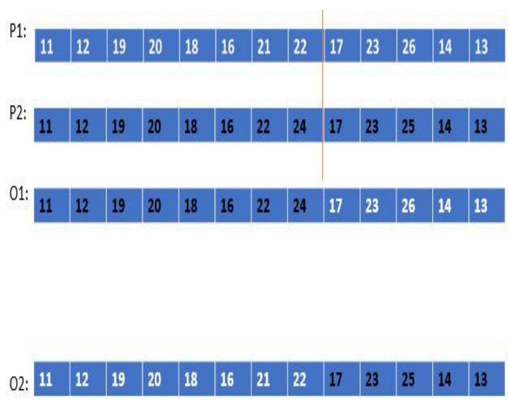

Fig. 6. Crossover between two population of network configuration

For both GA we used 0.05 mutation rate with a single point mutation.

5. RESULT AND PERFORMANCE ANALYSIS

A sample demand for 24 hours shown in figure above and sample hourly breakdown of energy sources had been taken to evaluate the performance of this algorithm. Ideal power scheduling was known before. To measure the similarity or performance a comparison with ideal scheduling with found scheduling in every generation had been taken.

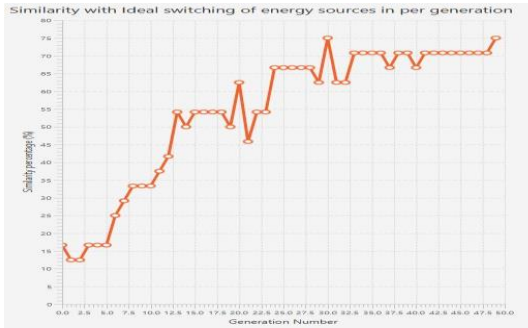

Fig.7. Comparison of similarity of power scheduling for every generation with ideal scheduling

Figure 8: Total line loss for 24 hours with power scheduling and network reconfiguration

Line loss increases slowly as more power sources are assigned according to demand-supply. In an earliergeneration, the line loss is lower. Because the power scheduling was not optimal. This is the Pareto-optimal condition when line loss increases but power scheduling performance increases.
In figure 7 the performance is found for 18 correct scheduling out of 24 with different and least loss possible network configuration (see Appendix I).

6. CONCLUSION

As the source can be scheduled simultaneously with network configuration, such scheduling can provide much efficacy of using renewable energy sources in an isolated or islanded area. Our proposed algorithm could be useful as an ideal condition with less power loss.

A genetic algorithm approach has been applied for optimizing dispatching power to a network with reconfiguring the network as well as scheduling the power sources. Our algorithm with carefully chosen parameters provides 76% similarity with ideal condition providing more than 1MW less line loss from the general condition. So, using more constraint and fitness property this algorithm can also work for any distributed system reconfiguration. In near future, we have the plan to run this algorithm with more constraint and objective functions so that renewable sources integrating with conventional power can also be scheduled with network reconfiguration. This will provide robust integrating of renewable sources with conventional power.

REFERENCES

[1] "Efficient electrical energy transmission and distribution," IEC, 2007, http://www.iec.ch/about/brochures/pdf/technology/transmission.pdf.

[2] S. Kalambe and G. Agnihotri, "Loss minimization techniques used in distribution network: bibliographical survey," Renewable and Sustainable Energy Reviews, vol. 29, pp. 184–200, 2014.

[3] A. C. Santos, A. C. B. Delbem, J. B. A. London Jr., and N. G. Bretas, "Node-depth encoding and multiobjective evolutionary the algorithm applied to large-scale distribution system reconfiguration," IEEE Transactions on Power Systems, vol. 25, no. 3, pp. 1254–1265, 2010.

[4] T. Niknam, J. Olamaie, and R. Khorshidi, "Hybrid algorithm based on HBMO and fuzzy set for multi-objective distribution feeder reconfiguration," World Applied Sciences Journal, vol. 2, pp. 308–315, 2008.

[5] J. E. Mendoza, M. E. Lopez, C. A. CoelloCoello, and E. A. ´ Lopez, "Micro genetic multiobjective reconfiguration algorithm ´considering power losses and reliability indices for medium voltage distribution network," IET Generation, Transmission and Distribution, vol. 3, no. 9, pp. 825–840, 2009.

[6] Y. Hayashi, H. Takano, J. Matsuki, and Y. Nishikawa, "Multiobjective optimization method for distribution system configuration using Pareto optimal solution," Electronics and Communications in Japan, vol. 94, no. 1, pp. 7–16, 2011.

[7] F.-Y. Hsu and M.-S. Tsai, "A non-dominated sorting evolutionary programming algorithm for multi-objectives power distribution system feeder reconfiguration problems," International Transactions on Electrical Energy Systems, vol. 23, no. 2, pp. 191– 213, 2013.

[8] B. Tomoiaga, M. Chindris ˘ ¸, A. Sumper, A. Sudria-Andreu, and R. Villafafla-Robles, "Pareto optimal reconfiguration of power distribution systems using a genetic algorithm based on nsgaii," Energies, vol. 6, no. 3, pp. 1439–1455, 2013.

[9] F. Rivas-Davalos, E. Moreno-Goytia, G. Guti ´ errez-Alacaraz, ´ and J. Tovar-Hernandez, "Evolutionary multi-objective opti- ´ mization in power systems: state-of-the-art," in Proceedings of the IEEE Lausanne POWERTECH, pp. 2093–2098, Lausanne, Switzerland, July 2007.

[10] T. D. Sudhakar and K. N. Srinivas, "Restoration of power network—a bibliographic survey," European Transactions on Electrical Power, vol. 21, no. 1, pp. 635–655, 2011.

[11] Gupta, K., & Sen, S. (2018). A Genetic Algorithm Approach to Regenerate Image from a Reduce Scaled Image Using Bit Data Count. BRAIN. Broad Research In Artificial Intelligence And Neuroscience, 9(2), pp. 34-44. Retrieved from http://brain.edusoft.ro/index.php/brain/article/view/805

[12] Sen, S., Gupta, K. D., & Ahsan, M. M. (2020). Leveraging Machine Learning Approach to Setup Software-Defined Network (SDN) Controller Rules During DDoS Attack. In Proceedings of International Joint Conference on Computational Intelligence (pp. 49-60). Springer, Singapore.

[13] Gupta, K. D., Dasgupta, D., & Sen, S. (2018, December). Smart Crowdsourcing Based Content Review System (SCCRS): An Approach to Improve Trustworthiness of Online Contents. In International Conference on Computational Social Networks (pp. 523-535). Springer, Cham.

[14] Khan, A., Gupta, K. D., & Haque, A. RESOLUTION ENHANCEMENT OF ELECTRON MICROSCOPIC VOLUME BY VOLUME RESTORATION TECHNIQUE.