Scheduling of Integrated Thermal Energy Storage with Cogeneration System using Firefly Technique

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Abstract— The use of Combined Heat and Power (CHP) with an overall effectiveness from 70 to 90% is one of the most effective solutions to minimize the energy utilization. Mainly caused by interdependence of the power as well as heat in these systems, the optimal operation of CHP systems is a composite optimization issue that require powerful solutions. This paper discourse the optimal day-ahead scheduling of CHP units with Thermal Storage Systems (TSSs). Fundamentally, the optimal scheduling of CHP units problem is a complex optimization problem with innumerable stochastic besides deterministic variables. The initial stage models behaviour of operating parameters and to minimizes the operation costs or price meantime the second stage examine the system's Thermal Storage Systems scenarios. The fruitfulness of the proposed algorithm has been examined. This paper illustrates Firefly algorithm (FA) to probe CHPED with Thermal Storage Systems with bounded feasible operating region. The main prospective of this technique is that it proper the fairness between local and global search. A comparative investigation of the FA with (RCGA), (NSGAII), (SPEA2) is introduced.

Key words: Thermal Storage Systems (TSSs), TSS Modelling, Cost Function, Firefly Algorithm (FA)

I. INTRODUCTION

A fleeting inspection into the energy storage approach currently available for the integration of oscillating renewable energy was execute [8,4,3]. These incorporate Pumped Hydroelectric Energy Storage (PHES), Underground Pumped Hydroelectric Energy Storage (UPHES), Battery Energy Storage (BES), Flow Battery Energy Storage (FBES), Compressed Air Energy Storage (CAES), Flywheel Energy Storage (FES), Thermal Energy Storage (TES), Super-capacitor Energy Storage (SCES), Superconducting Magnetic Energy Storage (SMES), Hydrogen Energy Storage System (HESS) and Electric Vehicles (EVs). The goal was to identify the following for each:

1) How it works?
2) Favorable circumstances
3) Applications
4) Cost
5) Detriments
6) Future

A brief contrast was then completed to designate the broad range of operating attribute available for energy storage technologies [12,6]. It was determined that PHES is the most likely stand-alone technology that will be employed in Ireland for the integration of fluctuating renewable energy. Although, the HESS, TESS, and EVs are the also very promising, yet require more research to eliminate uncertainty surrounding their merits and costs. For a few countries, CAES could be a more acceptable technology than PHES depending on the availability of suitable sites. FBES could also be employed in the future for the integration of wind, while it may not have the scale need to exist along with electric vehicles. The left-over technologies will most probably be used for at the present applications in the future, but further developments are unlikely.

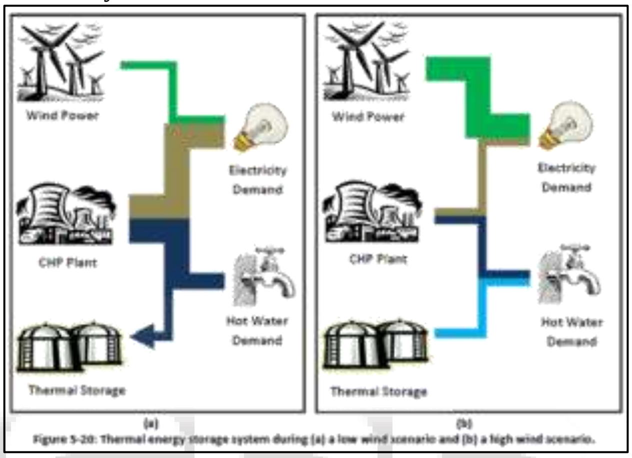


Fig. 1.1:

A. Thermal Energy Storage (TES)

Thermal energy storage demands storing energy in a thermal reservoir so that it can be recapture at a later time. A group of thermal applications are familiar with instead of electricity to furnish heating and cooling containing Aquifer Thermal Storage (ATS), and Duct Thermal Storage (DTS) [9,5,2,10]. Although, these are heat generation techniques as compared to energy storage techniques and hence there will not be discussed in detail here. In terms of storing energy, there are two primary thermal energy storage possibilities.

B. Thermal Energy Storage System (TESS)

The thermal energy storage system can equally be used very effectively to increase the flexibility enclosed by an energy system. As previously mentioned in this report, by integrating various sectors of an energy system, rise wind penetrations can be achieved because of the additional flexibility created. Unlike the hydrogen energy storage system which enabled connection between the electricity, heat as well as transport sectors, thermal energy storage only combine the electricity and heat sectors with one another. By establishing district heating into an energy system, then electricity as well as heat can be facilitate from the same provision to the energy system using Combined Heat and Power (CHP) plants [13,15,14,16,17,11,1,7]. This brings supplementary flexibility to the system which validates larger penetrations of intermittent renewable energy resources.

C. Overview

Vitality stockpiling advancements are significant parts in most vitality frameworks and could be a vital apparatus in accomplishing a low-carbon future. These advancements take into account the decoupling of vitality free market activity, generally providing a profitable asset to framework administrators. There are numerous situations where vitality stockpiling organization is focused or close aggressive in the present vitality framework. In any case, administrative and economic situations are habitually poorly prepared to remunerate capacity for the suite of administrations that it can give. Moreover, a few innovations are still excessively costly relative, making it impossible to other contending advancements (e.g. adaptable age and new transmission lines in power frameworks).

D. Key Findings

- Energy storage technologies are beneficial in most energy systems, with or without high levels of variable renewable generation. In the modern scenario, some smaller-scale systems are cost relentless or nearly competitive in remote section and off-grid exercises. Substantial scale warm capacity methods are focused for taking care of warming and cooling demand in incalculable areas
- Individual storage technologies generally have the capability to supply multiple energy and power services. The optimal responsibility for energy storage varies be depending on the current energy system landscape and future developments outstanding to each region.
- To constrain power area decarburization in the Energy Technology Perspectives (ETP) 2014 2DS, an expected 310 GW of supplementary matrix associated power stockpiling limit would be required in the United States, Europe, China and India. Huge warm vitality stockpiling and off-framework power stockpiling potential additionally exists. Extra information is required to supply a more thorough appraisal and ought to be organized at the national level.
- Market configuration is the crucial to quickening arrangement. Continuous approach situations and economic situations for the most part cloud the cost of vitality administrations, making gigantic value mutilations and resultant in business sectors that are deficient to compensate vitality stockpiling innovations for the appropriate favors that they can convey.
- General public speculation in energy storage research and development has led to remarkable price reductions. In spite of, additional efforts (like targeted research and development investments and demonstration projects) are required to further drop energy storage price and accelerate development.
- Thermal energy storage systems become visible to well-positioned to decline the amount of heat that is currently frittered away in the energy system. This waste or needless heat is an underutilized resource, in part due to the quality and quantity of both heat demand and resources is not fully familiar.

E. Thermal Storage System (TSS) Modeling

Thermal storage system (TSS) modeling and constraints are presented in this section. The constraints of thermal storage system include the limits of thermal storage which is like an ESS constraints.

Thermal storage limits in each period:

$$H_{storage}(t) = HCAP_{storage} \quad \forall\ t \tag{1}$$

Thermal storage maximal discharge limits:

$$HD_{storage}(t) \le (0.4 \times HCAP_{storage}) \times X(t) \quad \forall\ t,\ X \in \{0,1\} \tag{2}$$

Thermal storage maximal charge limits:

$$HC_{storage}(t) \le (HCAP_{storage}) \times Y(t) \quad \forall\ t,\ Y \in \{0,1\} \tag{3}$$

The thermal storage cannot charge and discharge at the same time in each time slice:

$$X(t) + Y(t) \le 1 \ \forall\ t,\ Y \ and \ X \in \{0,1\} \tag{4}$$

Thermal storage maximal discharge limits in each period "t", considering the battery state storage in period t-1:

$$HD_{storage}(t) - H_{storage}(t-1) \le 0 \quad \forall\ t \tag{5}$$

Thermal storage maximal charge limits in each period ''t'', considering the battery state storage in period t-1:

$$HC_{storage}(t) - H_{storage}(t-1) \le HCAP_{storage} \quad \forall\ t \tag{6}$$

State balance of the thermal storage:

$$H_{storage}(t) = H_{storage}(t-1) - HD_{storage}(t) + HC_{storage}(t-1) \quad \forall\ t \tag{7}$$

Initial state of the thermal storage:

$$HD_{storage}(t=0) \le (0.4 \times HCAP_{storage}) \quad \forall\ t \tag{8}$$

Thermal power balance:

$$HE_{Demand}(t) = H_g(t) - HD_{storage}(t) - HC_{storage}(t) \quad \forall\ t \tag{9}$$

F. Cost Function

The problem in the proposed case includes conventional power units, conventional heat units and cogeneration units. Convex input-output operational curves for conventional power and heat only units are considered which indicate their cost functions will be convex too. Thus, given problem have combined heat and power units with convex quadratic cost functions. The cost function for each unit individually can be obtained by multiplying input-output curve with fuel cost burned in that unit. Thus, cost function can be represented as the sum of cost functions for all the units separately as given below:

$$C_b(H_b) = \alpha_b + \beta_b H_b + \gamma_b H_b^2 \tag{10}$$

$$C_e(P_e) = \alpha_e + \beta_e P_e + \gamma_e P_e^2 \tag{11}$$

$$C_{chp}(P_{chp}, H_{chp}) = \alpha_{chp} + \beta_{chp} P_{chp} + \lambda_{chp} P_{chp}^2 + \delta_{chp} H_{chp} + \psi_{chp} H_{chp}^2 + \xi_{chp} P_{chp} H_{chp} \tag{12}$$

$$F(X) = \sum_{e=1}^{E} C_e(P_e) + \sum_{chp=1}^{CHP} C_{chp}(P_{chp}, H_{chp}) + \sum_{b=1}^{B} C_b(H_b) \tag{13}$$

Where,

e, b, chp are the indices of power only units, heat only units and combined heat and power units respectively and E, B, CHP are the number of conventional power units, conventional heat units and combined heat and power units.

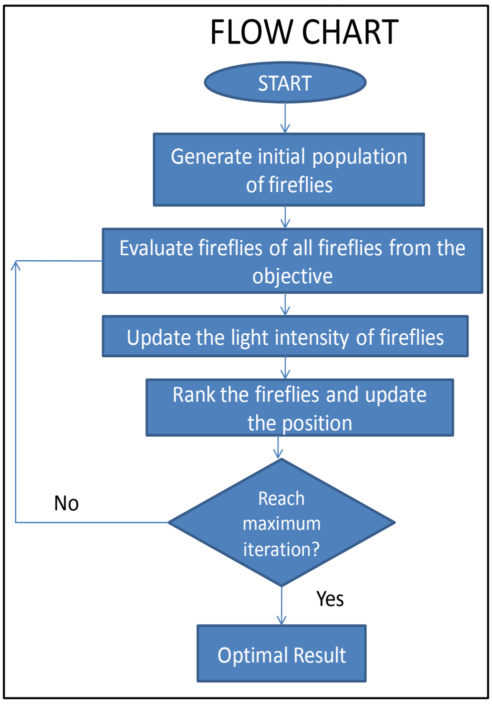
II. FIREFLY ALGORITHM

Firefly algorithm has been effectively carryout to explain distinctive power frameworks difficulties. Economic dispatch issue has been settled utilizing firefly calculation and its answer gives predominant outcome then other optimization calculation. In, firefly algorithm has been utilized in recurrence control in combined cycle gas turbine control plant for improvement of controller picks up. FA is one of the ongoing swarm intelligence techniques created by Yang [10] in 2008 and is a sort of stochastic, nature-propelled, meta-heuristic calculation that can be connected for taking care of the hardest optimization issues (additionally NP-difficult issues). This algorithm has a place with stochastic calculations. This implies it utilizes a kind a sort of randomization via looking for an arrangement of arrangements. It is motivated by the flashing lights of fireflies in nature. Heuristic signifies 'to find' or 'to find arrangements by experimentation'.

A. *Structure of the Firefly*

Firefly calculation is picked here as an improvement apparatuses. This algorithm depends on a physical recipe of light power I those reductions with the expansion in the square of the separation r2. In spite of this, as the separation from the light source builds, the light ingestion causes that light ends up weaker and weaker. Because of the arbitrary idea of firefly algorithm numerous trails are performed to get the best outcomes. The engaging quality of firefly is encoded with the minimization of clog cost which is dictated by its brightness or light force. The calculation for the proposed clog administration issue is appeared in Firefly calculation has four parameter α0, β0 γ0 and population size n. Positioning of FA by their power with current best arrangement gives proposed results. In the meantime, ideal arrangement of generator rescheduling diminishes the blockage. The adequacy of proposed firefly calculation for blockage or congestion administration is contrasted and the execution of other calculation in this work.

B. *Flow Chart of Fire Fly Algorithm*



III. RESULTS & DISCUSSION

To validate the effectiveness of the proposed FA algorithm for CHPED problem, two test systems with non-convex and non-linear characteristics are considered. The feasible operating reason of four test system cogeneration units is shown in Figure. The HFA for the complex problem CHPED with considering heat and power limit and losses including value point effect results are compared with the other algorithm to show the effectiveness and superiority of the proposed algorithm. The results are obtained by implemented the algorithm by using FORTRAN-90 on personal computer (1.66 GHz, Pentium-IV, with 512 MB RAM PC). The algorithms are operated for 100 individuals and 200 iterations for setting of HFA control parameters. In this paper, best, worst and mean results of applying algorithms for different trial along with their computation time are presented. The presented method applied to the different test system to show the effectiveness of the proposed method. After many trails of proposed method parameter set.

Parameter		
	FA	HFA
Swarm size(M)	60	60
Number of society (Ns)	5	5
Inertia weight	Wmax = 0.9, wmin = 0.4	Wmax = 0.9, wmin = 0.4
Acceleration coefficients	CL = 2, CSL1 = 0.5, CSL2 = .5, CSM1 = 0.25, CSM2 = 0.75,	CL = 2, CSL1 = 0.5, CSL2 = .5, CSM1 = 0.25, CSM2 = 0.75
Acceleration coefficients for HCSO		CSL1 =2.05, CSL2 = 2.05, CSM1 = 2.05, CSM2 = 2.05

Table 1: Parameter setting of FA and HFA algorithms

A. *Test System 1*

The test system consists of 7 units in which four are power generation units, two units are cogeneration units and one is heat unit. For two cogeneration units the feasible operating region is shown in Fig (----).The feasible operating reason equations for test systems 1 of cogeneration units are as follows:

1) *Test System 1*

$1.781914894 \text{ x } h5 - p5 - 105.7446809 \leq 0$
$0.1777777784 \text{ x } h5 + p5 - 247.0 \leq 0$
$- 0.169847328 \text{ x } h5 - p5 + 98.8 \leq 0$
$1.158415842 \text{ x } h6 - p6 - 46.88118818 \leq 0$
$0.151162791 \text{ x } h6 + p6 - 130.6976744 \leq 0$
$-0.067681895 \text{ x } h6 - p6 + 45.07614213 \leq 0$

The parameters of test system 1 is shown in Table 1 which include the limits of power generation of conventional unit, heat and active power of cogeneration unit and heat production of heat unit and also shows the power and heat coefficient of conventional, cogeneration and heat units. The total demand of heat and power are 150MWth and 600MW respectively.

IV. Conclusions

This paper proposes a new technique HCSO for solving CHPED problems. All the complications present in CHPED problems can be handled effectively by HCSO. The results clearly illustrate its effectiveness. Proposed technique HCSO is not only cost efficient but also it gives better results in terms of best fuel cost, computational time and power loss. A new hybrid civilized swarm optimization approach is developed by embedding constriction based particle swarm with society-civilization algorithm to solve complex combined heat and power economic dispatch. A set of CHPED problems are solved by CSO and HCSO algorithms. The PSO algorithms show poor performance, whereas the CSO is very effective in giving quality solutions consistently for CHPED problems with less computational time.

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