Scope of Intelligence Approcahes for Unit Commitment Under Uncertain Sustainable Energy Environment For Effective Vehicle To Grid Operations-A Comprehensive Review

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Abstract. Electric vehicles are getting popularity as these are eco-friendly and could be a part of power sector in the future. Electric Vehicles are the smart hybrid vehicles, which stores electric power during their operation, which could be stored in storage cells. These electric vehicles may be plug-in electric vehicles or battery operated electric vehicles. The concept of aggregators may be utilized, wherein the stored energy in vehicles could be supplied to grid during parking hours .This also facilitate the consumers to sale power during the high power demand and purchase power during low power demand. Thus, a bi-directional flow of power could be possible either from vehicle to grid or vice-versa. A large penetration of electric vehicles could result in increase in power demand which could be compensated by proper coordinated unit commitment and optimization techniques. The increasing load on grid by the impact of demand and trends in small generating units which require proper selection of number of generating units to put in line and other units in off condition calls for the concept of unit commitment. It is the selection of more efficient units to be in service and shutting down the other unit while maintaining all the other constraint constant. This would result in effective power flow in an economic manner, simultaneously maintaining the adequacy and reliability of the system. The proposed research represents the scope of intelligence algorithm for unit commitment problem with effective solution of vehicle to grid operations along with sustainable energy for realistic power system.

1. INTRODUCTION

In the era of development and advancement in technology, electrical power plays a vital role as power is essential commodity for the functioning of any industrial growth. As the main source of electrical energy are fossil fuel energy sources which are diminishing rapidly and would lead to an end one day. This requires careful attention to make systematically and economically the use of these resources. Also ,the power generation companies needs to motivate the small power industries to motivate the small power generation units to take part in the contribution to take part in the contribution to decrease the threads of power crisis. As a necessity one should make enough attempts to utilize non-conventional energy sources so that the burden on conventional energy source could be reduced to a larger extend. This would result in more and more involvement of sustainable energy sources. But as we know that these sources are intermittent energy sources, as they do not provide a constant output power. Transforming present energy system towards one emphasized by renewable energy comes with some challenges, leads to make proper co-ordinate use of conventional and sustainable energy sources provides the optimum power generation and transmission could be possible maintaining all the constraints constant. Secondly, the invent of hybrid electric vehicles could also play an important role to reduce the dependency on conventional energy source. Thus, the proposed research proposal is the development of a hybrid system which combines the overall features of unit

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commitment, renewable energy sources with the effect of hybrid electric vehicles.

2. LITERATURE REVIEW

Electrical power is generated by various power generating units such as thermal, hydro, nuclear, solar and wind etc. These generating units are required to turn on and off in proper sequence, while doing so the expense of on off/ should be minimum. This process of analysis and continuously changing generating schedule is referred to as unit commitment (UC)[1].Unit commitment is an optimization problem used to select the operation schedule at each hour interval with changing loads within permissible limit. Also due to large penetration of intermittent sources led to more complex in satisfying the supply and demand. Esmaeeli et al.[2] in his work suggested that with increase in wind power, power generation flexibility must increase as well. Jonghe et al. [3] describes the various complexities introduced in generation schedule by these intermittent sources . Shahriar et al. [4] presents a new technique to solve problems due to renewable energy penetration by formulating a Mixed Integer Linear Programming (MILP) technique. Further, Wang et al. [5] presents the increased complexity due to introduction of large electric vehicles as new participants in the existing power system. However, Vehicle to grid (V2G) can help to improve the reliability and stability of the grid, alleviate power shortages, and reduce peak power, spinning reserve, voltage and frequency regulation .Yang et al. [6] proposed a hybrid meta-heuristic method for solving mixed integer unit commitment problem integrating with significant plug-in electric vehicles. These electric vehicles can act as storage cells when large number of batteries are connected to form aggregators. These aggregators may be used as spinning reserve thus reducing dependency on conventional generating sources. The combined activity of the hybrid power system should be utilized appreciably in intellectual manner to effectively produce economic generation schedule. This calls up for new novel algorithms for providing more optimal solutions to these hybrid UC problems .Dynamic programming (DP)[7], Lagrangian relaxation(LR)[8],Harmony search (HS)[9], Particle swarm optimization (PSO)[10],Genetic algorithm(GA)[11] are some of the recent optimization methods to handle conventional UC problem. Seth et al. [12] in his work describes improved priority list method to effectively a ramp rate constrained unit commitment.Table-1 presents a comprehensive review of some related intelligent and innovative approach to tackle complex UC problems.

Table-1: Comprehensive review of UC papers

Author	Year of Publication	References	Brief Review	Constraints
A. Y. Saber and G. K. Venayagamoorthy	2009	[10]	This paper presents a discrete particle swarm optimization technique used to optimize the scheduling of gridable vehicles. PSO method used also reduces operation cost by charging the vehicles from renewable sources or utility during off-peak load when price is low and discharge to grid at peak load when price is high (V2G)	Power balance, V2G, Spinning reserve, Generation limits, Vehicle parking limits, Transmission constraints
M. Singh, I. Kar, and P. Kumar	2010	[13]	This paper presents simulation of actual data of Guwahati city with due effect of EV penetration .It is observed that coordinated charging and discharging patterns not only flatten the voltage profile but also reduces the transmission losses	Slow Charging, Medium Charging , Fast Charging, EV Coordinated
B. Palmintier and M. Webster	2011	[14]	In this research, unit commitment problem is combined with into a single mixed-integer optimization which focuses on the dynamic thermal power system .Also suggested that for achieving carbon emission targets policy makers may approach by providing incentives to customers to gain regulatory goals	Economic Dispatch, Generation Expansion, Expansion planning, Operating Reserve
C. De Jonghe, E. Delarue , R. Belmans, and	2011	[3]	In this research, an alternative methodology is introduced which provides system flexibility with	Operational Constraints, Must run level, Ramp rate constraints, Maintenance

W. D'haeseleer			better storage capacity. It also provides analysis of the impact of a high level wind penetration on the optimal generation by combining screening curve methodology with a linear programming (LP)	Constraints
S. Kamboj, W. Kempton, and K. S. Decker	2011	[15]	This paper presents a deployed multi-agent system which integrate electric drive vehicles to grid. These power regulations markets depends upon ancillary (eg. Spinning reserve) and non-ancillary (eg. peak power) services. A detailed study of V2G, system equipment's and associated accessories for power flow within the standard constraint.	Maximum rate of charging, Maximum regulation-up power, Maximum regulation-down power
G. O. Suvire, M. G. Molina, and P. E. Mercado	2012	[16]	In this research, dynamic model is developed which stores energy produced due to wind generation and integrated with microgrids. This hybrid system controls voltage, frequency and smooth's active fluctuations due to DG penetration.	Dc link voltage, variable speed, Sudden change in load
A. Foley, B. Tyther, P. Calnan, and B. Ó Gallachóir	2013	[17]	In this research, of EV charging in the single whole electricity market in Ireland is analyzed. EV charging under peak and off-peak charging scenario's is examined. It is seen that introduction of V2G technology increases power system flexibility and facilitates more penetration of wind power	Ramp rate up and down, Minimum up and down time, Emission coefficients
Provas Kumar Roy	2013	[18]	In this research, behavior of all the masses in the universe due to gravitational forces logic is applied to thermal unit commitment problem. The proposed algorithm is tested using Matlab programming and results are compared with other known algorithms for six systems during a schedule of 24H.	unit capacity limit, ramp rate limits, spinning reserve constraints, minimum up time and down time constraints
L. Liu, H. Li, Y. Xue, and W. Liu	2014	[19]	In this research, reactive power is compensated using compensation algorithm which tackles system operation issues with improved system stability and reliability. Exact power distribution is made by proper coordination between power variables. Thus, proposed method effectively improves system performance in terms of stability and reliability.	maximum power point tracking, Reactive power, Capacitor charging
M. E. El-Hawary	2014	[20]	This research presents the benefits of smart grid such as environment and socio-economic. It also presents the dynamic interactive, real time infrastructure and building the	Charging and Discharging Constraints

			power system of the future through smart grid. It also provides all information, possibilities, polices and benefits in designing a smart intelligent system	
Yaowen Yu, Peter B. Luh, Eugene Litvinov, Tongxin Zheng, Senior, Jinye Zhao, and Feng Zhao	2014	[21]	This research presents a combined Markovian and Interval unit commitment to solve the problem of congestion created due to uncertain nature of wind generation. In this method global node states are taken care by interval optimization and local nodes states are handled by Markovian strategy.	Start-up constraints, Minimum up/down, ramp rate constraints, generator capacity constraints
V.K. Kamboj , S. K. Bath, J. S. Dhillon	2015	[22]	In this research, local search ability of DE is improved by utilizing random search approach to enhance exploitation phase and is then applied to UCP. The hybrid system is tested for standard benchmark function and engineering problems for 30 trials and 500 iterations.	Power balance constraints, Spinning reserve , Thermal constraints
C. CHEN , S. DUAN	2015	[23]	In this research, impact of different charging /discharging patterns on microgrids is analyzed using genetic algorithm and economic schedule is evaluated for a	Minimum/maximum power limits, Energy capacity

			typical grid-connected microgrid. Three modes of operation are presented. A balance energy exchange between PHEVs and microgrids is presented with reduced cost and improved efficiency.	
H. LIU, P. ZENG, J. GUO, H. WU, and S. GE	2015	[24]	In this research, controlled EV charging strategy with due consideration of sustainable power outputs is effectively employed using genetic algorithm. Furthermore, considering the limitations of sustainable energy sources, the developed hybrid system provides improved economic scheduling	Charging and Discharging Constraints
S. Umamaheswaran and S. Rajiv	2015	[25]	In this paper, a review of benefits and barriers of renewable energy generation subjected to various financial and social constraints are studied. It further reviews the emerging trends and barriers in the financing landscape and analyses the impact of policy performance in this context.	Wind and solar uncertainties
N. Zhang, Z. Hu, X. Han, J. Zhang, and Y.	2015	[26]	This paper presents a novel unit commitment model using fuzzy sequence which	Power balance constraint, Spinning reserve constraint Minimum

Zhou			effectively modifies constraints to eliminate the hurdles posed due to uncertain characteristics of sustainable energy sources. It further explains how the power available in storage cell act as a reserve during unavailability of wind power while satisfying the demand with low cost and improved efficiency.	on/off time constraint, Upper limit of wind power penetration rate
K. S. Reddy, L. K. Panwar, and R. Kumar	2015	[27]	This paper presents reserve system in unit commitment in deregulated market by the participation of electric vehicles as an responsive reserve to enhance power system reliability at reasonable cost. It further encourage to earn more revenue from the required reserve facility in the event of outage or sudden demand by satisfying through electric vehicle as reserve.	Load balance constraint, Responsive reserve constraint, Thermal unit constraints, Minimum up/ down time, Ramp up/down rates
L. Yang, J. Jian, Z. Dong, and C. Tang	2016	[28]	In this research, proposed method converts the conventional UC problem into a mixed integer linear programming by combining several small non-linear problems and provides better solutions with less iterations and also reduced simulation time as compared to original method.	Linear and non- linear constraints
W. S. Tan and M. Shaaban	2016	[29]	In this research, MILP formulation is used for solving ramping capability and operating reserve problem related to traditional UC by implementing a chance constraint set. Further, to improve computational efficiency, constraint set is adjusted using projected disjunctive programming.	Probabilistic chance constraint
V. K. Kamboj , S.K. Bath , J.S. Dhillon	2016	[9]	In this research, exploitation phase is enhanced by combining random search algorithm for solving UC problem. This hybrid scheme inspired from musical tunes is found to be divergence free and able to handle discrete and continuous variables without prior setting of variables. Thus, it utilizes various inherent qualities to provide effective solution for a particular optimization problem	Load balance constraint, Reserve constraint, Thermal unit constraints
R. Á. Fernández, F. B. Cillerue lo, and I. V. Martínez	2016	[30]	In this research, extended range electric vehicle (EREV) based in a fuel cell electric vehicles (FCEV) set model is presented to achieve better efficiency and performance. This article shows various possibilities of	Cut-off voltage, Charging Constraints, Discharging constraints

			increased run-range, fuel-efficiency by the combined action of electric vehicle, combustion engine and hydrogen fuel. A combined effect of all these participants will result in better performance and accurate energy management.	
K. S. Reddy, L. K. Panwar, R. Kumar, and B. K. Panigrahi	2016	[31]	In this paper fireworks algorithm is developed to improve dual objective function including both emissions and cost using Electric vehicles and Renewable energy technologies. In this paper author effectively utilizes the logic of sparkles travel in space to find the objective function	Load balance constraint, Reserve constraint, Thermal unit constraints
V. Monteiro, J. G. Pinto, and J. L. Afonso	2016	[32]	This research presents, a hybrid prototype battery charger which operates in five different modes which includes charging vehicles and dispatching power either from V2G and G2V.Also, based on the available research theory, advantages, benefits and control strategies of proposed smart grid model are elaborately described.	Charging and Discharging Constraints
Z. Bie, H. Xie, G. Hu,	2016	[33]	In this research, a novel optimal scheduling is	Power balance, Ramp

and G. Li			employed using decoupling technique to satisfy demand response and improve economy by controlling randomness in generation .Further, it reveals that operational cost will vary according to customer power usage and wind uncertainties.	constraints, Operation time constraints, Spinning reserve constraints, Customer satisfaction constraints, Demand power constraints
E.S. Ali, S.M. Abd Elazim, A.Y. Abdelaziz	2016	[34]	This study describes that power transmission losses may be reduced by using PV system and wind generation through distributed generation. In the proposed ant lion algorithm allocation and sizing of DG sources generates optimum power with minimum losses.	Power conservation constraint, Voltage constraint, DG limits constraint, Line Capacity Constraint
C. Deckmyn, J. Van de Vyver, T. L. Vandoorn, B. Meersman, J. Desmet, and L. Vandevelde	2017	[35]	In this research, charging schedule for EV participation to improve system security and reduction in emission cost is presented. A heuristics-based optimization methodology for a day-ahead unit commitment (UC) model in microgrids is proposed. The model aims to schedule the power among the different microgrid units while minimizing the operating costs together with the CO2 emissions produced	Load balance constraint, Emission cost constraint.
M. Ban,	2017	[36]	In this research,	power

J. Yu, M. Shahidehpour, and Y. Yao			a solution for imbalance between supply and demand is provided by using benders decomposition method. The power imbalance between utility and demand is absolutely handled by P2H technology which converts excess wind power by electrolysis process. The ultimate result of this combination with G2P facilitate accumulation of excess wind power.	balance constraints ramping up/down limits, unit generation limits, spinning reserve
S. Chandrashekar, Y. Liu, and R. Sioshansi	2017	[37]	In this research, benefits of flexible charging hours on the wind uncertainties and variability is given to reduce the cost while charging all times. In this article various span of V2G and G2G is presented which is to be effectively utilized so that consumer can earn more profit from power sell.	Ramp-up constraints, charger capacity, state-transition logic
A. Babin, N. Rizoug, T. Mesbahi, D. Boscher, Z. Hamdoun, and C. Larouci	2017	[38]	In this research, solution to battery charging for reducing the cost has been implemented in a software tool. Problems related to aging, battery sizing in commercial electric vehicle (EV) using intelligent charging so as to increase total cost of consumer are effectively solved.	Charging and Discharging Constraints
H. Li, A. T. Eseye, J. Zhang, and D. Zheng	2017	[39]	This paper presents a new algorithm called as regrouping swarm optimization to improve performance by simulating the system over a day and results are recorded with and without wind penetration .The system can effectively use for commercialization of power. Performance objective includes minimization of fuel cost, operation and maintenance cost.	Grid power exchange limits, Demand-supply balance, ESS units charging/discharging power limits, ESS units dynamic operation performance
J. Meus, K. Poncelet, and E. Delarue	2018	[40]	In this research, fast approximation solution to UC problem is provided by grouping similar plants into clusters such that the binary commitment variables are replaced by a single integer variable. This grouping helps to convert binary commitment variables into a single integer variable. This method combines CUC with conventional UC to reduce errors introduced due to problem formulation and grouping of non-identical units and provide a feasible and optimal solution.	System Constraints, Technological constraints
J. Liu, C. D. Laird, J. K.	2018	[41]	In this research, convergence rate and solution quality is	Minimum uptime and downtime constraints

Scott, J. P. Watson, and A. Castillo			improved by building an algorithm. An attempt is made to find an global optimal solution but lacks in capturing desired computational time. However, except computational time, the algorithm efficiently solves the UC-AC problem.	spinning reserve constraint, startup/shutdown costs
F. H. Aghdam and M. T. Hagh	2018	[42]	In this research, problems of transmission lines and operation constraints including MUT/MDT and emission limits are analyzed using MICA algorithm. In this method, basic algorithm uses priority list (PL) method to define initial state. The system is tested on IEEE-30 bus and 118-bus system	Minimum uptime and downtime constraints spinning reserve constraint, startup/shutdown costs
A. Yazdandoost, P. Khazaei, R. Kamali, and S. Saadatian	2018	[43]	In this research, generating schedule is controlled to minimize the total operating cost by introducing modified genetic algorithm based on multicellular organism's mechanisms. This algorithm combines the features of GA and modified GAMOM. The effectiveness of the scheme is validated through the nature of convergence curve.	Power Balance, Generating Units limitation, Ramp up and down limitation, Startup and shutdown Constraints, Voltage and Angle constraints.
X. Fang, L. Bai, F. Li, and B. M. Hodge	2018	[44]	In this paper, a hybrid model is developed which shows mapping of individual unit commitment status with CCGTs. The hybrid model consists of combined-cycle gas turbines which provides excellent operational flexibility, better response to sustainable sources, ability to generate more power compare to conventional method.	Minimum online/offline time and ramping rates
C. Zhu, F. Lu, H. Zhang, and C. C. Mi	2018	[45]	In this research, temperature sensitive nature of lithium-ion batteries, finite robust predictive strategy is presented for reduce heat effect to damage system. Further proposed method facilitate to predict future temperature forecast and enables to provide flexibility to driving profiles.	Heating and cooling constraints, Unit generation limits
S. Maghsudlu and S. Mohammadi	2018	[46]	This research presents a novel stochastic Monte Carlo optimization algorithm to handle uncertainties of solar power. This study includes the investigations in presence of EV and PV. Also, an efficient balance is seen between uncertain energy source and EV system.	Generation limits, Vehicle balance
X. Chen, M. B. Mcelroy, Q. Wu, Y. Shu,	2018	[47]	This paper presents practical barriers while dealing with operation of collaborative functioning of	Penetration level of renewables**,** Emission Constraints

and Y. Xue			uncertain distributed generation and simultaneously maintaining emission and environmental constraints within limit.	
T. K. Renuka, P. Reji, and S. Sreedharan,	2018	[48]	This paper presents a multistage PSO method for improving both the energy penetration and small signal stability. This method is tested on IEEE 14-bus at 220 KV practical system with the solar and wind power. The program is carried out in two stages. In first stage renewable penetration is addressed while in second stage stability issue is handled.	Equality constraints, Inequality constraints, Fast voltage stability indices, Line stability index
T. Ghose, H. W.Pandey, K. R. Gadham	2019	[49]	This paper describes about two risk assessment techniques which predicts the option of providing power either according to demand response or renewable energy source. The main objective of this research is to focus mainly on financial risk of aggregators while maintaining the conditions of technical aspects of microgrids.	Minimum and maximum capacity of the DR, minimum and maximum durations of load recovery.
M. Bayati, M. Abedi, G. B. Gharehpetian, and M. Farahmandrad	2019	[50]	In this research, EV power output effects on the conventional fuel cost is presented in very lucid manner. Also, benefits of EV technologies are properly utilized to tackle problems related to environmental pollution. Frequency deviation due to EV power output is handled by V2G technology.	Power balance, Charging /Discharging constraints
J. B. Mogo and I. Kamwa	2019	[51]	This paper presents a security constraint unit commitment is implemented and effectively reduces burden of spinning reserve on spinning reserve requirement on conventional sources by utilizing wind power as a reserve using mixed integer programming thereby reducing the overall operating cost.	Ramping reserve limits, spinning reserve capacity limit.
Z. Yang, K. Li, Y. Guo , S. Feng , Q. Niu , Y. Xue , A.Foley	2019	[6]	The paper presents a binary symmetric method which solves the complexity of hybrid system in presence of uncertain sources and electric vehicles. Particle swarm optimization algorithm is utilized to provide flexible charging/discharging patterns thereby reducing the cost of generation and emission.	Generation limit, Power demand limit, Power reserve limit, Minimum up/down time limit

3. MATHEMATICAL MODELING

The objective of unit commitment is to plan the optimal schedule of available generating units to minimize the total operational and generation cost. Total cost of power generation includes fuel cost, shut down and start-up costs within constraints limit.

The various constriants are as follows:

3.1 Operating Cost

The operating cost of i[th] at h[th] hour and can be represented as below:

$$F_{hi} = (a_i P_{hi}^2 + b_i P_{hi} + c_i)U_{hi} + SUC_{hi}(1 - U_{(h-1)i})U_{hi}$$

(₹/h)

$$(i = 1, 2, ..., NG; hr = 1, 2, ..., H) \quad (1a)$$

Where, Fhi is the cost associated with the i[th] generating unit at h[th] hour and a_i, b_i and c_i are its fuel and operational cost coefficients, U_{hi} and $U_{(h-1)i}$ is the committed status of the ith unit at h[th] hour and (h-1)-th hour respectively, SUC_{hi} is the start-up cost of i[th] unit at h[th] hour

Combined cost (F_h), for all the generating units (NG) at a particular hour 'h' can be obtained as the sum total of all the individual units 'costs:

$$F_{hr} = \sum_{i=1}^{NG} [(a_i P_{hi}^2 + b_i P_{hi} + c_i)U_{hi} + SUC_{hi}(1 - U_{(h-1)i})U_{hi}]$$

₹/h (hr =1, 2…, H) (1b)

Now, the total fuel cost F is the double summation of the costs incurred for all the generators for all the time periods considered. It can be mathematically represented as:

$$F = \sum_{h=1}^{H} \left(\sum_{i=1}^{NG} [(a_i P_{hi}^2 + b_i P_{hi} + c_i)U_{hi} + SUC_{hi}(1 - U_{(h-1)i})U_{hi}] \right)$$

(₹/h) (hr =1, 2… H) (1c)

Mathematically, startup cost (SUC_{hi}) can be expressed as:

$$SupC_{hi} = \begin{cases} HSC_i; & M\,Dt_i \le T_{hi}^{OFF} \le (M\,Dt_i + CsH_i) \\ CSc_i; & T_{hi}^{OFF} > (MDT_i + C\,sH_i) \end{cases}$$

$$(i = 1, 2, ..., NG; hr = 1, 2, ..., H) \quad (2)$$

where, CSc_i and HSC_i are cold startup and hot start-up cost of i-th unit respectively and MDt_i is the minimum down time of i-th unit, T_{hi}^{OFF} is duration for which the i-th thermal unit has been continuously off until hour h. CSH_i is the cold start hour of i-th unit. The start-up cost for a unit depends on its downtime. If it is longer than the related MDt plus its predefined Cold-Start Hours (CsH), Cold-Start Cost (CSc) is needed to operate it. Else if the i-th unit down time is shorter than the mentioned duration, Hot-Start cost (HSC) is needed to operate it. The Various Constraints linked with unit commitment problem are explained below.

Maximum (max) and Minimum (min) Operating Limits of Generators

Every unit has its own maximum/minimum power level of generation, beyond and below which it cannot generate.

$$P_{i(\min)} \le P_{hri} \le P_{i(\max)} \quad (i = 1, 2, ..., NG; \quad hr = 1, 2, ..., H)$$

(3)

Load Balance Constraints

The load balance or system power balance constraint requires that the sum of generation of all the committed units at hth hour must be greater than or equal to the demand Dh at a particular hour 'h'.

$$\sum_{i=1}^{NG} P_{hri} U_{hri} + P_{hr}^{Sustainable} = D_{hr} \quad (hr = 1, 2, ..., H) \quad (4a)$$

Case-1: During Charging of Vehicle

$$\sum_{i=1}^{NG} P_{hri} U_{hri} + P_{hr}^{Sustainable} = D_{hr} + D_{hr}^{Vehicle} \quad (hr = 1, 2, ..., H) \quad (4b)$$

Case-2: During Discharging

$$\sum_{i=1}^{NG} P_{hri} U_{hri} + P_{hr}^{Sustainable} + D_{hr}^{Vehicle} = D_{hr} \quad (hr = 1, 2, ..., H) \quad (4c)$$

Above eqn.(4) does not contain power loss in the system. If hourly power loss Ph_L is considered, then eqn.(4) can be modified as:

$$\sum_{i=1}^{NG} P_{hri} U_{hri} + P_{hr}^{Sustainable} = D_h r + P_{hrL} \quad (hr = 1, 2, ..., H) \quad (5a)$$

Case-1: During Charging of Vehicle

$$\sum_{i=1}^{NG} P_{hri} U_{hri} + P_{hr}^{Sustainable} = D_{hr} + P_{hrL} + D_h^{Vehicle} \quad (hr = 1, 2, ..., H)$$

(5b)

Case-2: During Discharging

$$\sum_{i=1}^{NG} P_{hri} U_{hri} + P_{hr}^{Sustainable} + D_{hr}^{Vehicle} = D_{hr} + P_{hrL} \quad (hr = 1, 2, ..., H)$$

(5c)

The power generation of the NG generating units at a particular time horizon handles theload balance constraint and other operating limit constraints. To satisfy the equality constraints, one unit is designated as reference unit and its power generation is decided as follows: For any arbitrarily available unit output power generation(Phi), $P_{i(\min)} \le P_{hri} \le P_{i(\max)}$, (i=1,2,...,NG), it is assumed that power output available at the Rth unit t is constrained by the load(power) balance equation as:

$$P_{hrR} = D_{hr} + P_{hrL} - \sum_{\substack{i=1 \\ i \neq R}}^{NG} (P_{hri} + P_{hr}^{Sustainable}) \qquad (hr = 1,2,...,H)$$

(6a)

Case-1: During Charging of Vehicle

$$P_{hrR} = D_{hr} + P_{hrL} - \sum_{\substack{i=1 \\ i \neq R}}^{NG} (P_{hri} + P_{hr}^{Sustainable} - D_{hr}^{Vehicle}) \qquad (hr = 1,2,...,H)$$

(6b) **Case-2: During Discharging**

$$P_{hrR} = D_{hr} + P_{hrL} - \sum_{\substack{i=1 \\ i \neq R}}^{NG} (P_{hri} + P_{hr}^{Sustainable} + D_{hr}^{Veh}) \qquad (hr = 1,2,...,H)$$

(6c)

Reserve Power (Spinning) Constraints

To deal with unpredictable disturbances (interruption of generation and transmission lines or unexpected increase in demand) certain amount of reserve capacity must be always available. This excess capacity of generation is known as Spinning Reserve (Rs) and mathematically given as:

$$\sum_{i=1}^{NG} P_{i(\max)} U_{hi} + P_{hr}^{Sustainable} \geq D_{hr} + R_{shr} \qquad (hr = 1,2,...,H)$$

(7a)

Case-1: During Charging of Vehicle

$$\sum_{i=1}^{NG} P_{i(\max)} U_{hri} + P_{hr}^{Sustainable} \geq D_{hr} + R_{shr} + D_{hr}^{vehicle} \qquad (hr = 1,2,...,H) \quad (7b)$$

Case-2: During Discharging

$$\sum_{i=1}^{NG} P_{i(\max)} U_{hi} + P_{hr}^{Sustainable} \geq D_{hr} + R_{shr} - D_{hr}^{Vehicle} \qquad (hr = 1,2,...,H) \quad (7c)$$

Thermal Constraints

A thermal constraint includes (a) minimum up time i.e. time required to turn-on a unit from shunt down condition (b) Minimum down time i.e. time required to turn –off already running units and (c) crew constraints i.e. limitations of crew members to attend more than one unit at the same time. These constraints may result in many hurdles in the operation of thermal units.

Minimum-up Time

Mathematically expressed as:

$$T_{hi}^{ON} \geq MUt_i \qquad (i = 1,2,...,NG; hr = 1,2,...,H)$$

(8a)

Where, T_{hi}^{ON} is time interval for which ith unit is continuously ON (in hrs) and MUt_i is its minimum up time (in hrs).

Minimum-down Time

Mathematically expressed as:

$$T_{hri}^{OFF} \geq MDt_i \qquad (i = 1,2,...,NG; hr = 1,2,...,H) \quad (8b)$$

where, T_{hri}^{OFF} is time interval for which ith unit is continuously OFF (in hrs) and MDt_i is it's minimum down time (in hrs).

Crew Constraints

If a plant consists of two or more units, there may not be enough crewmembers to attend all the units simultaneously while starting up.

Initial Operating Status of Generating Units

Its decides minimum up /down time satisfaction of every unit depending upon data of last day's previous schedule

4. Constraints Repairing Mechanism

The flowchart for constraint handling mechanism during charging and discharging phase has been depicted below. The Fig.1 shows the constraint handling mechanism for UCP minimum up and down time. And Fig.2 represents the constraints handling mechanism for spinning reserve requirements.

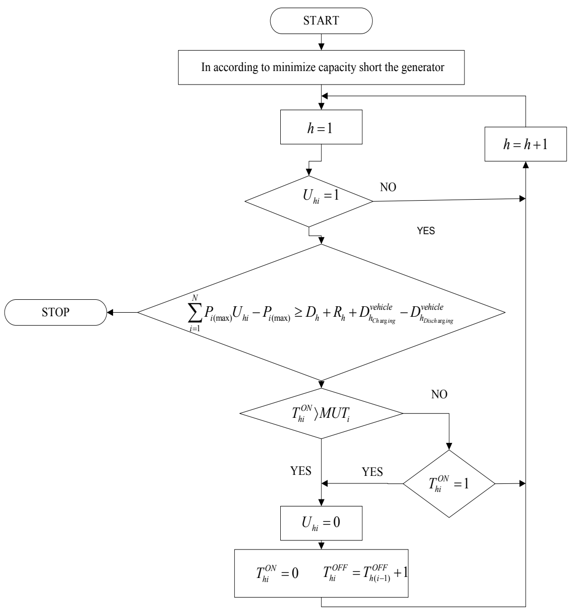

Fig.1: Handling of MDT and MUT during charging and

Discharging Phase

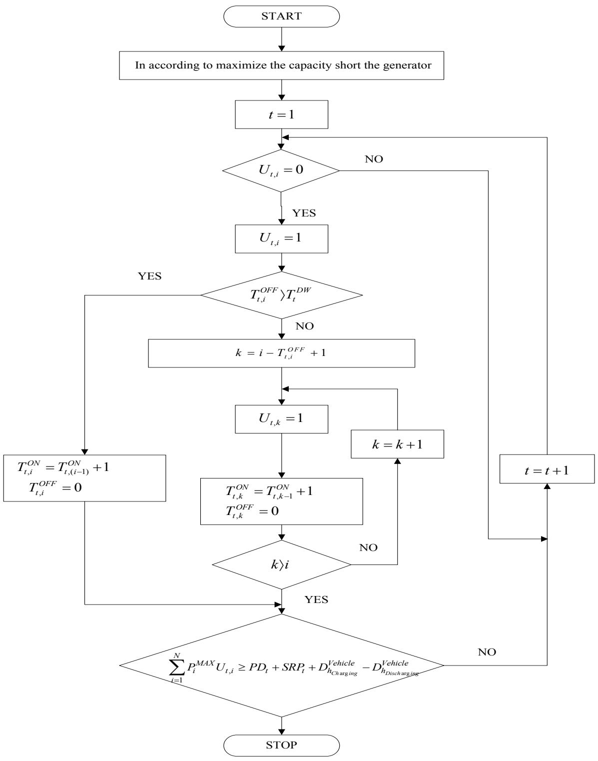

Fig.2: Fulfillment of spinning reserve requirements during charging and Discharging Phase

5. SCOPE OF RESEARCH

The analysis of present review suggest that UC problem is aimed at determining the turn-On and turn –off schedules of thermal units to meet forecasted demand for a certain time interval and belongs to a combinatorial optimization problem. Further, it is clear that optimization falls roughly into three categories: heuristic search, mathematical programing, and hybrid methods. There are several optimization strategies employed to solve the complexity of generation scheduling and dispatch problem. Some of these methods are the, Bat Algorithm, Binary Gravitational Search Algorithm, Backtracking Search Optimization, Colliding Bodies Optimization, , Chaotic Krill Herd Algorithm, Dynamic Programming, Dragonfly Algorithm, Fireworks Algorithm , Flower Pollination Algorithm, Grey Wolf Optimizer, Imperialist Competitive Algorithm, , Mine Blast Algorithm, Optics Inspired Optimization, Random Walk Grey Wolf Optimizer, Simulated Annealing, Sine Cosine Algorithm, Search Group Algorithm, Symbiotic Organisms Search, Salp Swarm Algorithm, Virus Colony Search, Water Cycle Algorithm , Water Wave Optimization, etc.

From the research paper listed above in Table-1 and research problem, it have been seen that great efforts are taken for achieving economic load dispatch and unit commitment problem using different methodologies, but there needs some more considerable efforts are made to find solution for global optimized solution (within local and global search space) for cost effective solution for unit commitment problem for vehicle to grid operation in sustainable energy environment, which seriously affects the optimality of the results. Also, it is clear from the literatures, appreciable efforts are made to solve the unit commitment problem using various meta-heuristics optimization methodologies, but no significant efforts are made to find out the global optimization search algorithm by combining local and global search capability of algorithm to get more improved results. Further, research theorem has logically suggested that none of the optimization algorithm is able to provide exact solution to all types of optimization problems efficiently. In other words, there is always scope of improvements to upgrade current techniques to better solve maximum optimization problems efficiently.

In recent research studies pertaining to optimization algorithm, it has been reported that swarm intelligence optimization have some drawbacks and need advanced solutions. Another important concern in swarm intelligent algorithm is regarding exploration, exploitation and convergence. In practical application, it creates serious problem. This motivated our attempts to propose yet another memetic solution of with due consideration of sustainable energy sources along with vehicle to grid concept.

6. Conclusion And Future Scope

In the proposed research, the authors has successfully presented the scope of solution intelligence solution strategies for effective vehicle to grid operation for unit commitment problem with due consideration of sustainable energy sources. Further, Electric vehicles are getting popularity due to eco-friendly nature and could be a part of power sector in the future. Thus, proposed research explores the concept of modern smart grid system along with effective solution strategies. It is recommended that, in order to explore the scope of intelligence approaches in future learning, the following future work may be taken into consideration:

- Consideration of memetic intelligence approaches for cost effective solution of unit-commitment due consideration of uncertainty of sustainable power and vehicle to grid operations.

- Development of hybrid optimization algorithm by combing local search algorithm with modern global search algorithm for constrained optimization problem can be explored and its performance testing can be made on various standard unimodal, multi model, fixed dimension and engineering benchmark problems.

- Simulation environment can be created for implementation of unit commitment problem of electric power system with due consideration of Vehicle to Grid operation in stochastic sustainable environment energy environment

- Testing and validation of proposed memetic intelligence algorithm can be explored for various IEEE benchmarks problems with incorporation of V2G operations in stochastic sustainable environment.

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