

OPTIMAL UNIT COMMITMENT USING JAYA OPTIMIZATION TECHNIQUE

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Abstract

The UC problem exists as the main optimization challenge which power systems use to operate their networks. The process of the problem involves finding the best power generator timetable which satisfies electricity needs while achieving the lowest costs and maintaining system dependability and all operational restrictions. The UC problem creates its challenges through its mixed-integer nonlinear structure which requires multiple operational constraints to be solved including generator capacity restrictions and minimum operational times and ramp rate limits and spinning reserve requirements. The UC problem has been solved by researchers who used traditional optimization methods which include Dynamic Programming and Lagrangian Relaxation and Mixed Integer Programming but these methods encounter problems because they need more computation power and show slow progress and cannot manage extensive systems. Recent years have seen metaheuristic optimization algorithms become popular because they provide a fast solution for difficult nonlinear optimization problems. JAYA optimization algorithm stands out as an easy-to-use yet effective solution among these optimization techniques. The JAYA algorithm operates as a population-based optimization method which uses no parameters for its operations because it brings candidate solutions closer to the best solution while pushing them away from the worst solution at every iteration. JAYA operates differently from most metaheuristic algorithms because it needs no special control parameters which makes its implementation easier and decreases the time needed to adjust its parameters. The review paper studies how the JAYA optimization algorithm operates in solving the Optimum Unit Commitment (OUC) problem which exists in power system operations. The paper presents the mathematical structure of the UC problem which includes the cost reduction objective and all operational restrictions. The research paper assesses how recent studies have used the JAYA algorithm to improve generation scheduling for both thermal and renewable energy systems. The study compares the JAYA approach to Genetic Algorithms, Particle Swarm Optimization, and Differential Evolution optimization methods to demonstrate its effectiveness. The study demonstrates that the JAYA algorithm achieves faster convergence while generating better solutions and requiring less processing power than most conventional and evolutionary optimization methods. The algorithm shows exceptional performance when it processes extensive power grid systems which include renewable energy sources like wind and solar energy. The JAYA optimization algorithm functions as an effective and advanced solution for contemporary unit commitment challenges which arise in smart grid systems.

Keywords: Unit Commitment, JAYA Optimization Algorithm, Power System Optimization, Economic Dispatch, Metaheuristic Algorithm, Renewable Energy Integration, Smart Grid.

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I. Introduction

Power system operators need to create efficient generation schedules because electricity demand keeps growing and power systems become more complex. The Unit Commitment (UC) problem stands as one of the core optimization challenges which power systems must solve to operate effectively. System operators must establish optimal schedules for generating units which operate during a 24-hour period. The operating cost typically includes fuel costs, start-up costs, and shut-down costs of generating units. Efficient unit commitment ensures that electricity demand is satisfied economically without compromising system stability and reliability. The UC problem becomes difficult to solve in real power systems because operational constraints create multiple challenges. These constraints include generator capacity limits, minimum up and down time requirements, ramp rate limits, spinning reserve requirements, and power balance constraints. The UC problem requires mixed-integer nonlinear optimization because it uses binary variables to represent generator ON/OFF status while power generation levels are represented through continuous variables. Traditional optimization methods face difficulty solving the UC problem because of its complex computational requirements which increase when applied to large power systems.

The unit commitment problem has been addressed through traditional optimization methods which have been used for several decades. The field of optimization has adopted Dynamic Programming (DP) and Lagrangian Relaxation (LR) and Mixed Integer Programming (MIP) and Priority List methods as common techniques. The methods produce optimal or near-optimal solutions yet their effectiveness diminishes when dealing with large systems that have multiple restrictions because of their computational needs and system size challenges and their slow solution rates. The methods face difficulties when dealing with modern power systems which involve nonlinear cost functions and uncertainties. The research community has turned to metaheuristic optimization methods as a solution to existing difficulties. Metaheuristic algorithms provide an efficient solution for searching extensive solution spaces while they are capable of solving optimization problems that involve both nonlinear equations and nonconvex functions. Genetic Algorithms (GA) and Particle Swarm Optimization (PSO) and Differential Evolution (DE) and Ant Colony Optimization (ACO) and Simulated Annealing (SA) serve as widely used metaheuristic methods which researchers applied to solve the UC problem. The algorithms provide better strategic options which enable the creation of superior solutions that solve difficult optimization challenges. The algorithms require users to perform detailed adjustments on multiple algorithm-specific settings which include the mutation rate and crossover probability and inertia weight and learning factors because this process adds to the difficulty of execution.

The JAYA optimization algorithm has been developed as a straightforward efficient metaheuristic method for solving engineering optimization challenges. The JAYA algorithm functions as a population-based optimization system which enhances candidate solutions by directing them toward the optimal solution while keeping them away from the search population's least valuable solution. The JAYA algorithm presents its most appealing characteristic through the design of its system which operates without any required parameters. JAYA operates without the need for specific optimization control parameters which are required by most other optimization algorithms. The system enables straightforward implementation because it eliminates the need for specific parameters which would have required time-consuming adjustments. The JAYA algorithm has proven effective in multiple power system optimization tasks which include

economic dispatch, optimal power flow, load forecasting and generation scheduling because of its straightforward nature and effective global search abilities. The JAYA algorithm enables efficient identification of the best generating unit schedule which meets all operational requirements in the unit commitment problem. The algorithm possesses the capability to manage both continuous and discrete variables while it effectively explores the solution space to achieve cost minimization of total operational expenses.

Modern power systems today require renewable energy sources including wind and solar power to function properly. The increasing use of renewable energy sources creates new challenges because they produce unpredictable power generation patterns. The unit commitment problem demands advanced optimization techniques which can handle both stochastic and dynamic system requirements. The JAYA algorithm has shown promising potential in dealing with such complexities due to its strong exploration and exploitation capabilities. The study investigates JAYA optimization algorithm applications to solve the optimal unit commitment problem in power systems. The study focuses on the mathematical formulation of the UC problem, including objective functions and operational constraints. The paper examines existing research which demonstrates how JAYA algorithm enhances power system optimization performance compared to both traditional methods and other metaheuristic techniques. The RYA algorithm shows its capacity to enhance solution quality while decreasing computational requirements and promoting renewable energy capacity according to the study. The study results indicate that JAYA optimization algorithm delivers an effective and dependable solution for contemporary unit commitment challenges found in smart grid systems.

II. Literature Survey

Researchers have conducted extensive research on the Unit Commitment (UC) problem because it plays a crucial role in ensuring both cost-effective and dependable operation of power systems. The complex scheduling problem has been addressed through the development of various optimization techniques. Power systems use unit commitment methods which include Dynamic Programming Lagrangian Relaxation and Mixed Integer Programming but these traditional methods become computationally expensive when they handle large power systems. The solution to this problem requires the introduction of multiple metaheuristic algorithms which include Genetic Algorithms Particle Swarm Optimization Differential Evolution and Ant Colony Optimization. The techniques enable better optimization of nonlinear problems through enhanced flexibility and improved convergence. The JAYA optimization algorithm has become popular because its design requires no parameters and it can efficiently conduct worldwide searches. The JAYA algorithm has proven its ability to reduce generation expenses while enhancing operational efficiency in unit commitment cases. The JAYA optimization method presents itself as an effective solution for contemporary power system optimization challenges.

Sr. No	Author / Year	Method / Algorithm	Key Contribution / Findings
1	Manikshetti & Kalage (2017)	Teaching Learning Based Optimization (TLBO)	Applied TLBO to solve the Unit Commitment (UC) problem and achieved improved convergence compared to classical methods.
2	Kadam et al. (2009)	Fuzzy Logic Algorithm	Proposed fuzzy logic approach for UC under uncertain operating conditions and improved decision-making capability.

3	Putra et al. (2016)	Genetic Algorithm (GA)	Solved thermal unit commitment with fuel constraints and demonstrated cost minimization with improved scheduling.
4	Saravanan & Vasudevan (2014)	Invasive Weed Optimization	Addressed emission-constrained UC problems and achieved lower generation cost with environmental consideration.
5	Zhao et al. (2018)	Binary Cuckoo Search Algorithm	Proposed improved binary cuckoo search for UC problems and achieved faster convergence with better solution accuracy.
6	Rao (2016)	JAYA Optimization Algorithm	Introduced the JAYA algorithm, a parameter-less optimization technique that improves solutions by moving toward the best candidate and away from the worst.
7	Kumar et al. (2021)	Metaheuristic Optimization	Investigated multiple optimization techniques for UC and highlighted their efficiency in solving large-scale scheduling problems.
8	Hussain & Ismail (2020)	Quantum Binary PSO	Proposed improved PSO algorithm to reduce operational cost in unit commitment scheduling.
9	Hong & Apolinario (2021)	Review of UC Models	Provided a comprehensive survey of uncertainty handling in UC models and discussed renewable integration.
10	Agarwal & Pal (2021)	Genetic Algorithm	Developed GA-based scheduling for economic UC and compared results with traditional optimization techniques.
11	Jiang et al. (2021)	Gas-Turbine UC Model	Developed UC model considering gas transmission constraints and reserve scheduling.
12	Postolov & Iliev (2022)	Adaptive Genetic Algorithm	Proposed adaptive GA for hydrothermal UC and demonstrated improved optimization performance.
13	Nazari & Fard (2022)	Heuristic Optimization	Developed heuristic optimization model for profit-based UC considering emission constraints.
14	Yin et al. (2022)	Risk-Averse Stochastic UC	Proposed stochastic UC model for hydro-thermal-wind systems considering uncertainty.
15	Qin et al. (2022)	Deep Reinforcement Learning	Developed ensemble reinforcement learning approach for solving UC problems with improved decision-making ability.
16	Ramesh & Li (2023)	Deep Learning Assisted UC	Proposed spatio-temporal deep learning model to reduce computational complexity in security constrained UC problems.
17	Kumar et al. (2023)	Metaheuristic Profit-Based UC	Developed optimization-based UC scheduling to maximize generator profit in competitive power markets.
18	Shah et al. (2024)	Hybrid Evolutionary Algorithm	Proposed hybrid evolutionary algorithm for solving mixed-integer nonlinear UC problems with improved solution feasibility.

19	Sakhavand et al. (2024)	Stochastic UC with DACE Model	Proposed design of computer experiments approach for stochastic UC and improved computational efficiency.
20	Shao et al. (2025)	Neural Column Constraint Generation	Introduced neural-based optimization framework to accelerate stochastic UC scheduling.

III. Proposed System

The system architecture which researchers designed for Optimal Unit Commitment uses JAYA Optimization Algorithm to find the best time schedule which generating units should work to fulfill load requirements while spending the least operational expenses. The system architecture starts with the collection of load demand and generation data from both thermal and renewable sources which serve as its initial input. The team establishes the unit commitment problem by creating an objective function and defining operational constraints which include power balance requirements and generation limits and spinning reserve limits. The JAYA optimization algorithm processes these inputs to discover the best solution available. The algorithm improves candidate solutions through a process which selects the best solution and discards the least effective solution from the existing population. The process results in an optimal schedule which achieves minimum fuel expenses while the system operates at full reliability. The final output is the optimized power generation schedule for the power system.

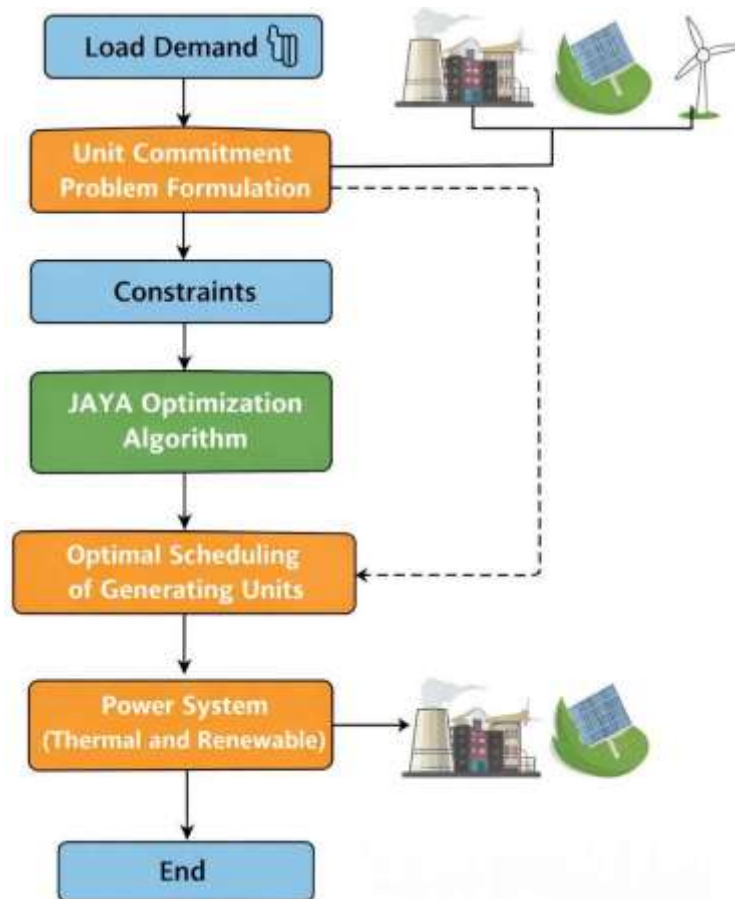


Fig.1. Proposed System

1. Load Demand

The block shows how much electrical power consumers need throughout a 24-hour period. The power system collects load demand data which serves as the main data input for solving the unit commitment problem. Power supply reliability depends on accurate load forecasting which also prevents power shortages and excess generation.

2. Unit Commitment Problem Formulation

This block contains the mathematical description of the unit commitment problem. The objective function calculates total operating costs which comprise fuel expenses and start-up and shut-down expenses. The formulation determines which generating units should be turned ON or OFF during different time intervals.

3. Constraints

The block contains all operational rules which power systems need to operate safely. The system uses power balance constraints and generator capacity limits and spinning reserve requirements and minimum up/down time requirements of generators as essential operational limits. The system uses these constraints to verify that all generated power meets load demands while the system remains stable.

4. JAYA Optimization Algorithm

The JAYA algorithm solves the unit commitment problem through its application. The technique uses population-based optimization to improve candidate solutions by directing them towards the best solution and away from the worst solution. The algorithm searches for the best generation unit combination through multiple iterations to achieve the lowest generation cost.

5. Optimal Scheduling of Generating Units

The system uses the JAYA algorithm to find the best ON/OFF positions and power levels for all generating units. This scheduling approach meets electricity demand requirements through its affordable operational costs and its enhanced system performance.

6. Power System (Thermal and Renewable Sources)

The current power generation system block demonstrates its ability to operate through thermal power plants together with solar and wind renewable energy sources. The JAYA algorithm provides an optimized schedule which these generating units use for their power production.

7. Output / End

The system produces its final output through an optimized generation schedule which reduces costs while ensuring system reliability and fulfilling electricity demand. This optimized solution enables power utilities to achieve better operational efficiency within their power systems.

JAYA Optimization Algorithm

The JAYA optimization algorithm serves as a population-based metaheuristic method which Rao developed in 2016 to solve complex optimization challenges. The algorithm's primary function executes through candidate solution movements which progress toward the optimal solution while blocking access to the least desirable solution throughout every loop. JAYA optimization algorithms operate without needing specific control parameters which include mutation rate and crossover probability for their implementation. The algorithm enables easy implementation because it requires no special control settings while users need to spend less time on parameter adjustment tasks. The JAYA algorithm assists in the unit commitment problem by finding the most efficient way to schedule generating units which decreases total generation costs while meeting all operational requirements. JAYA functions as a power system optimization solution because it provides fast solution development and easy-to-use functions.

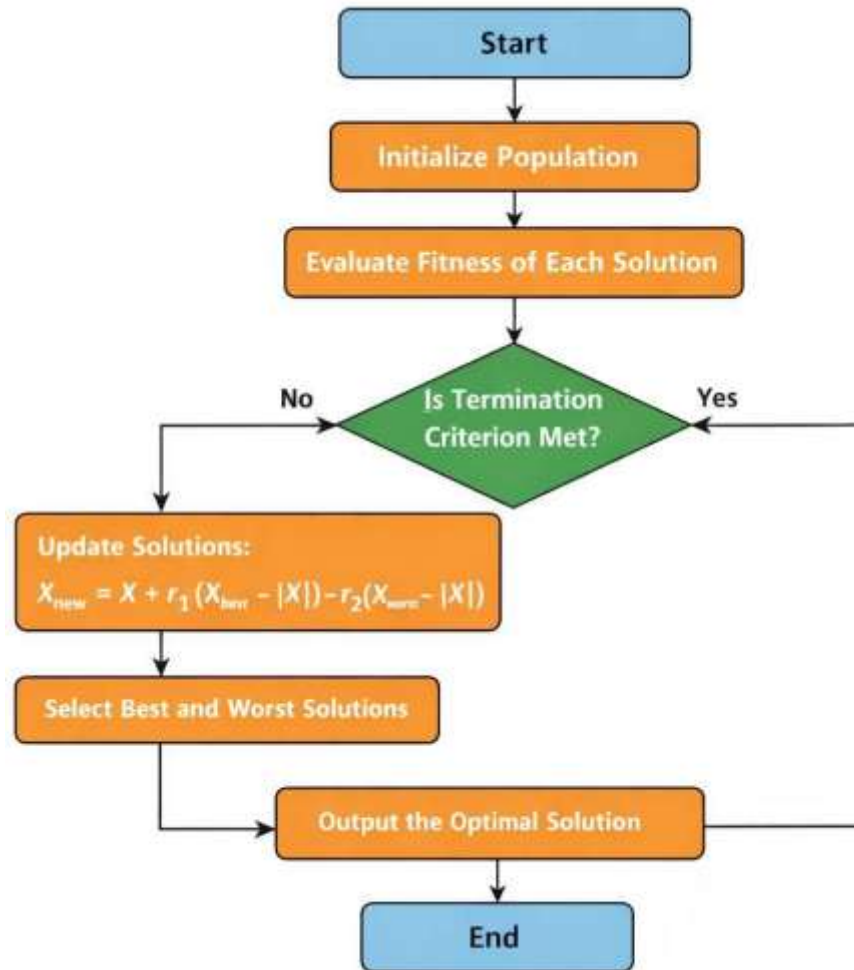


Fig.2. Flow Chart

IV. Conclusion

The Unit Commitment (UC) problem serves as a fundamental component for maintaining both economic efficiency and reliable functioning in contemporary power systems. System demand and operational constraints must be met through efficient scheduling of generating units which helps to decrease operating expenses. Standard optimization techniques struggle to solve the UC problem because it contains both nonlinear elements and complex systems that require solution for extensive power networks. Advanced optimization methods function as essential tools which help researchers create superior outcomes within acceptable limits of computational time. The JAYA optimization algorithm serves as the main focus of this paper which shows its application for solving the Optimal Unit Commitment problem through a comprehensive review. The JAYA algorithm functions as an effective and straightforward metaheuristic optimization method which develops candidate solutions by directing them toward optimal results while protecting against optimal results. The JAYA algorithm provides a significant benefit because it eliminates the need for specific algorithm parameters which makes its implementation easier while needing less time for parameter adjustment.

The study shows that JAYA algorithm outperforms multiple traditional optimization methods because it achieves faster convergence rates and delivers better solution results. The system can manage various operational constraints while supporting operations across extensive power networks. The algorithm enables power system operators to incorporate wind and solar renewable energy sources into their current grid systems. The JAYA optimization algorithm functions as an effective and promising method to resolve the unit commitment problem. Future research can focus on hybrid optimization techniques and real-time applications of the JAYA algorithm to further enhance power system performance and reliability.

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