

PAPER • OPEN ACCESS

Preface Lekantara Annual Conference on Engineering and Information Technology (LiTE)

To cite this article: 2022 *J. Phys.: Conf. Ser.* **2394** 011001

View the [article online](#) for updates and enhancements.

You may also like

- [A COMPARISON OF FLARE FORECASTING METHODS. I. RESULTS FROM THE "ALL-CLEAR" WORKSHOP](#)
G. Barnes, K. D. Leka, C. J. Schrijver et al.
- [Properties of Flare-imminent versus Flare-quiet Active Regions from the Chromosphere through the Corona. II. Nonparametric Discriminant Analysis Results from the NWRA Classification Infrastructure \(NCI\)](#)
K. D. Leka, Karin Dissauer, Graham Barnes et al.
- [Investigation and Determination of Electrochemical Reaction Kinetics in Lithium-Sulfur Batteries with Electrolyte LiTFSI in DOL/DME](#)
Sean Grabe, Matthew Dent, Shumaila Babar et al.

Preface Lekantara Annual Conference on Engineering and Information Technology (LiTE)

Lentera Akademika Nusantara (Lekantara), an Indonesian scientific publisher, organized **Lekantara Annual Conference on Engineering and Information Technology (LiTE)** on November 30, 2021 held fully virtual. The conference aims to exchange knowledge and research finding among academicians, researchers, professionals, policy makers, and postgraduate students.

The Awareness to increase the number of publications on the results of research that has been done deserves appreciation from all parties. Thus, Lekantara provides motivation and space for researchers to disseminate their research and accommodate their results of research. **Lekantara Annual Conference on Engineering and Information Technology (LiTE)** is one out of six conferences held by Lekantara in 2021.

Lekantara Annual Conference on Engineering and Information Technology (LiTE) was chosen to be implemented virtually due to the Covid-19 pandemic that is still spreading. The event is virtually implemented with a model that all invited speakers are given time to present their material for 30 minutes every invited speaker and after that a question and answer is carried out with the participants with a direct questioning system, through chat forums and Q&A forums provided by the zoom application. Overall, the conference took 5 hours the number of participants who joined the zoom room was recorded at participants. Participants came from few countries, namely Indonesia, Malaysia, Vietnam, Philippine, United States of America, UAE, and United Kingdom.

Lekantara Annual Conference on Engineering and Information Technology (LiTE) is implemented with the support of a stable internet network system and a zoom application. In the implementation there were several technical obstacles encountered by the participants, namely the difficulty of joining the zoom application due to the unstable internet signal. The holding of a virtual conference felt less meaningful, due to the lack of interaction between speakers and participants

Lekantara Annual Conference on Engineering and Information Technology (LiTE) committee received 132 manuscripts and a total of 132 papers were presented and discussed. The papers were authored by researchers from Indonesia, Malaysia, Vietnam, Philippine, United States of America, UAE, and United Kingdom

All papers have been scrutinized by a panel of reviewers who provide critical comments and corrections, and thereafter contributed to the improvement of the quality of the papers and scope. 91 papers were selected and eligible to be published in the proceeding.

We sincerely express our gratitude to the international/national advisory committee, presenters, organizing committee members, session chairs, all members of organization, participants, contributors and all the members of **Lekantara Annual Conference on Engineering and Information Technology (LiTE)**. Last but not the least, we are thankful to IOP JPCS Conference Series for producing the proceeding.



Organizing Committee

General Chair:

Aulia Luqman Aziz (CEO of Lekantara)

General Co-Chair:

Dr. Astri Rinanti, M.T. (Universitas Trisakti, Indonesia)

Secretary:

Retno Fitri Habsari Juniar Ayun (Managing Director of Lekantara)

Dindha Ayu Mitra Dyani (Lekantara)

Treasurer and Finance Chair:

Elly Rahmawati (Lekantara)

Velda Bellaretta (Lekantara)

Publication Chair:

Dr. Robbi Rahim (STIM Sukma Medan, Indonesia)

Website and Social Media Chair:

Adinda Firda Khoirunnisa (Lekantara)

Chandra Rismawan (Lekantara)

Editors

1. Assoc. Prof. Dr. Qammer H. Abbasi (University of Glasgow, UK)
2. Assoc. Prof. Ts. Dr. Hasliza A. Rahim (Universiti Malaysia Perlis, Malaysia)
3. Dr. Lisa Oksri Nelfia, S.T., M.T., M.Sc (Universitas Trisakti, Indonesia)
4. Andhyka Muttaqin, MPA (Universitas Brawijaya, Indonesia)

Organizing Institutions

- Lentera Akademika Nusantara (Lekantara)
- Universitas Trisakti

Table of contents

Volume 2394

2022

◀ Previous issue Next issue ▶

1st Lekantara Annual Conference on Engineering and Information Technology (LiTE)
01/10/2021 - 01/10/2021 Online

Accepted papers received: 22 November 2022

Published online: 26 December 2022

[Open all abstracts](#)

Preface

OPEN ACCESS 011001

Preface Lekantara Annual Conference on Engineering and Information Technology (LiTE)

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 011002

Peer Review Statement

[+ Open abstract](#) [View article](#) [PDF](#)

Algorithm and Modeling

OPEN ACCESS 012001

Vise Kriterijumska Optimizacija I Kompromisno Resenje (VIKOR) Algorithm for Analysis as Supporting System

K Prihartono Aksan Halim, Hendra Jatnika, Agus Alim Muin, Dian Agustini, Muthia Farida, Nur Hidayati, Ari Waluyo and Rulinawaty


[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012002

Neural Network Back-Propagation Method as Forecasting Technique

Teguh Iman Hermanto, Ali Idrus, Lipur Sugiyanta, Darmeli Nasution and Ikhsan Gunawan

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012003
This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see our Privacy and Cookies policy. 

ARAS Algorithm as Decision Support System's Technique for Selection Student Creativity Program

Aries Abbas, Debi Masri, Pungkas Prayitno, H Hasanuddin, Z Zaenuddin, Fitrah Yuridka,

Mokhamad Ramdhani Raharjo and Yohny Anwar

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012004

Restricted Boltzmann Machine and Matrix Factorization-Alternating Square Algorithm for Development Tourist Recommendation System

Yohanssen Pratama, Rianthi Angrainy Sianturi, Dedi Chandra, Kristopel Lumbantoruan and

Indah Trivena Tampubolon

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012005

Evaluation and Performance Analysis using ANP and TOPSIS Algorithm

Dana Marsetiya Utama, Reza Putri Parameswari and Ahmad Mubin

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012006

A Novel Hybrid Multi-Verse Optimizer Algorithm for Energy-Efficient Permutation Flow Shop Scheduling Problem

Dana Marsetiya Utama, M. Faisal Ibrahim, Danang Setiya Wijaya, Dian Setiya Widodo and Meri Dines Primayesti

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012007

Backpropagation Artificial Neural Network Enhancement using Beale-Powell Approach Technique

Roy Nuary Singarimbun, Ondra Eka Putra, N L W S R Ginantra and Mariana Puspa Dewi

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012008

Comparison Fletcher-Reeves and Polak-Ribiere ANN Algorithm for Forecasting Analysis

Eka Hayana Hasibuan, Surya Hendraputra, GS Achmad Daengs and Liharman Saragih

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012009

Implementation and Development of Learning Vector Quantization Supervised Neural Network

Retno Devita, Ruri Hartika Zain, Hadi Syahputra, Evan Afri and Intan Maulina

[+ Open abstract](#) [View article](#) [PDF](#)

Artificial Neural Network Model for Forecasting Natural Disasters: Polak-Ribiere and Powell-Beale Comparison

Eva Rianti, Firna Yenila, A A G B Ariana, Yesri Elva and Novi Trisna

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012011

Rough Set: Utilizing Machine Learning for the Covid-19 Vaccine

Silfia Andini, Nur Arminarahmah, GS Achmad Daengs, Sara Surya and Muhammad Afdhal

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012012

Analysis Instruments Using Decision System Concepts

Syariful Alam, Dayan Singasatia, Hendri Sembiring, Murwani Wulansari, Dedi Suhendro and Ilham Syahputra Saragih

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012013

Dynamics System for Construction Modelling

Diah Sarasanty and Erna Tri Asmorowati

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS

012014

Feature Extraction and Naïve Bayes Algorithm for Defect Classification of Manalagi Apples

Moch. Lutfi, Hasan Syaiful Rizal, Mochammad Hasyim, Muhammad Faishol Amrulloh and Zulfatun Nikmatus Saadah

[+ Open abstract](#) [View article](#) [PDF](#)

Algorithms and Complexity

OPEN ACCESS

012015

Python Based Machine Learning Text Classification

Siti Mujilahwati, Miftahus Sholihin, Retno Wardhani and M. Rosidi Zamroni

[+ Open abstract](#) [View article](#) [PDF](#)

Artificial Intelligence, Computer Networks and Communications

OPEN ACCESS

012016

Implementation Learning Vector Quantization Using Neural Network for Classification of Ear, Nose and Throat Disease

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see our Privacy and Cookies policy.



Samsir Samsir, Nelly Khairani Daulay, Syaiful Zuhri Harahap, Wahyuni Fithratul Zalmi, Afni Nia Sari, Fitri Aini Nasution and Ronal Watrianthos

[+ Open abstract](#) [View article](#) [PDF](#)

Computer Vision and Image Analysis

OPEN ACCESS 012017

Image Segmentation using Color Value of the Hue in CT Scan Result

Sedia Simbolon, Juju Jumadi, K Khairil, Y Yupianti, Liza Yulianti, S Supiyandi, Agus Perdana Windarto and Sri Wahyuni

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012018

Convolutional Neural Network for object Identification and Detection

Silfia Andini, Erni Rouza, Luth Fimawahib, Satria Riki Mustafa, Ahmad Fathoni, Teguh Iman Hermanto and Anggi Pratama Nasution

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012019

Convolutional Neural Network and Deep Learning Approach for Image Detection and Identification

Eka Pandu Cynthia, Edi Ismanto, M. Imam Arifandy, S Sarbaini, N Nazaruddin, Melda Agnes Manuhutu, Muhammad Ali Akbar and Abdiyanto

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012020

Brain Image Decomposition on Image Alteration

Sri Rahmawati, GS Achmad Daengs, Teri Ade Putra, Abdi Rahim Damanik and Anjar Wanto

[+ Open abstract](#) [View article](#) [PDF](#)

Control Engineering and Electric Automation

OPEN ACCESS 012021

Increasing the Compressive Strength of Concrete Using PPC

Arusmalem Ginting

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012022

Design of Direct Current Motor Speed Controlled Anchor Based on Root Locus Method

Rismawaty Arunglabi, Nicolaus Allu and Merlin

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see

[Privacy and Cookies policy](#) [View article](#) [PDF](#)



OPEN ACCESS 012023

Analysis of Performance on Pump Test Equipment Series and Parallel

Salma Salu, Jusuf Siahaya, Kriatiana Pasau, Karel Tikupadang and Danang Haryo Yudanto

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012024

A Design And Build A Robot Vacuum Cleaner

Charnia Iradat Rapa, Erick Dephtios, Chrisna Mariangga and Naomi Patiung

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012025

Utilization of Arduino on Electric Motor Starting

Matius Sau, Yoel Jeanri and Yusril Azarya Monasri

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012026

Design of wind power plant with a turbine capacity of 300 Watt

Hestikah Eirene Patoding, Yolgi Jaya Octaf, Ezriel Dukku, Yulianus Songli and Musa B. Palungan

[+ Open abstract](#) [View article](#) [PDF](#)

Control System

OPEN ACCESS 012027

Android Remote Control System using wireless connection

Ahmad Sujana, Ninik Sri Lestari, Rosmalina, Hendi Suhendi and Mohamad Abduh

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012028

Realtime Monitoring Design of Solar Cell Power Plant Based on IoT

Eodia T. Sedan Lobo, Poisson Rownaldy Takaya and Ivanto Bin Paledung

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012029

Development of Four Nossel Cross Flow Turbine

Corvis L Rantererung, Titus Tandiseno and Mika Mallisa

[+ Open abstract](#) [View article](#) [PDF](#)

Data Analysis, Computational Methods and Algorithms Optimization

OPEN ACCESS 012030

Analytical and Control Process Algorithm for Define of Water Meter

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see [our privacy policy](#)



Agung Widarman, Indra Riyana Rahadjeng, Isnurrini Hidayat Susilowati, Siti Sahara and Muhammad Toyib Daulay

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012031

Data Mining K-Means Algorithm for Performance Analysis

Agung Triayudi, Iksal and Reni Haerani

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012032

Data Centre Risk Analysis Using ISO 31000:2009 Framework

Johanes Fernandes Andry, Lydia Liliana, Hendy Tannady and Abdul Samad Arief

[+ Open abstract](#) [View article](#) [PDF](#)

Education

OPEN ACCESS 012033

Online Student-worksheet Based on Toulmin Argumentation Pattern in Physics Learning

D Sulisworo and Inri Safitri

[+ Open abstract](#) [View article](#) [PDF](#)

Intelligent Computation and Engineering Applications

OPEN ACCESS 012034

Android-Based Application for User Complaint as to Support SLA Implementation

Fatsyahrina Fitriastuti, Ryan Ari Setyawan, Yogi Ari Sudewo and Jeffry Andhika Putra

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012035

Internet of Things Implementation for Development of Smart Agriculture Applications

Ninik Sri Lestari, Andrew Ghea Mahardika, Sukirno, Herawati and Hermawaty

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012036

Convolutional Neural Network Approach and Implementation Sensor Design for Detecting Object

Suherman, S Lucky Trasya, M. Ari Ihsan, R Ali Hanafiah and Marwan Al-Akaidi

[+ Open abstract](#) [View article](#) [PDF](#)



Material and Characteristics Analysis

OPEN ACCESS 012037

Hot Water Extraction on Aspal Buton

Muhammad Saleh, Setyawati Yani and Nurjannah

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012038

Analysis Waste Material of Construction on Concrete Column

Helen Adry Irene Sopacua and Luciana Buarlele

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012039

Analysis of Tensile Tests and Microstructures of ST. 37 Steel Undergoing Carburizing Process Using Coal Powder

Atus Buku, Salma Salu, Merliana Pangadongan and Junsen Bryan Bia

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012040

The used of rubber material as additive in testing characteristics ac-wc using Nanggala river stone.

Ari Kusuma, Alpius and Sakaria Randepadang

[+ Open abstract](#) [View article](#) [PDF](#)

Mechanical Instrument Design and Structure Research

OPEN ACCESS 012041

Road Reconstruction Modelling and Challenge in Indrapuri Sub-District, Aceh Besar Regency

Syahrizal, Muttaqin Hasan and Taufiq Saidi

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012042

Principal Component Analysis Application for Determining Factors Influencing Drainage Construction Process in Residential Areas

Yulisa Amalia, Eldina Fatimah and Cut Zukhrina Oktaviani

[+ Open abstract](#) [View article](#) [PDF](#)

OPEN ACCESS 012043

Reconstruction and Maintenance Priority Buildings in Aceh Besar Regency

Salman, Mirza Irwansyah and Muttaqin Hasan

This site uses cookies. By continuing to use this site you agree to our use of cookies. To find out more, see

[Privacy and Cookies policy](#) [View article](#) [PDF](#)



OPEN ACCESS

012044

A Dynamics System of Modelling for Construction Development

Diah Sarasanty and Erna Tri Asmorowati

[+ Open abstract](#)



[View article](#)



[PDF](#)

OPEN ACCESS

012045

Smart Parking System with LabView Simulator

Rahmad Hidayat, Herawati, Andrew Ghea Mahardika, Ninik Sri Lestari, Sukirno and Givy Devira Ramady

[+ Open abstract](#)



[View article](#)



[PDF](#)

JOURNAL LINKS

[Journal home](#)

[Journal Scope](#)

[Information for organizers](#)

[Information for authors](#)

[Contact us](#)

[Reprint services from Curran Associates](#)



physicsworld

**Scientific meetings
catalyse research
success**

Nobel laureate
Stanley Whittingham
discusses how
Electrochemical
Society meetings
have helped him
advance his research
and career



The Electrochemical Society
Advancing solid state & electrochemical science & technology



Read the
full interview on
physicsworld.com

[Click to read article](#)



PAPER • OPEN ACCESS

A Novel Hybrid Multi-Verse Optimizer Algorithm for Energy-Efficient Permutation Flow Shop Scheduling Problem

To cite this article: Dana Marsetiya Utama *et al* 2022 *J. Phys.: Conf. Ser.* **2394** 012006

View the [article online](#) for updates and enhancements.

You may also like

- [Thermal inkjet bioprinting triggers the activation of the VEGF pathway in human microvascular endothelial cells *in vitro*](#)
Luis H Solis, Yoshira Ayala, Susana Portillo *et al.*
- [Biofabrication of vasculature in microphysiological models of bone](#)
Ian T Whelan, E Moeendarbary, David A Hoey *et al.*
- [Fourier Transform Methods in Hydrodynamic Modulation Voltammetry](#)
D. T. Schwartz, P. Stroeve and B. G. Higgins

A Novel Hybrid Multi-Verse Optimizer Algorithm for Energy-Efficient Permutation Flow Shop Scheduling Problem

Dana Marsetiya Utama^{1*}, M. Faisal Ibrahim², Danang Setiya Wijaya³, Dian Setiya Widodo⁴, Meri Dines Primayesti¹

¹University of Muhammadiyah Malang, Indonesia

²Universitas Internasional Semen Indonesia, Indonesia

³Universitas Trunojoyo Madura, Indonesia

⁴University of 17 Agustus 1945 Surabaya, Indonesia

*dana@umm.ac.id

Abstract. Recently, The issue of energy consumption has become an issue that is often considered, and the manufacturing sector contributes to the most significant proportion of this problem. Energy-Efficient Permutation Flow Shop Scheduling Problem (EPPFSP) is an effective way to solve this problem. This research offers a new algorithm Hybrid Multi-Verse Optimizer Algorithm (HMVO). Six experiments are presented to minimize total energy consumption. In addition, the Genetic algorithm (GA) and Ant Colony Optimization (ACO) algorithms were used as comparison algorithms. The experimental results show that HMVO requires low iterations to solve small and medium EPPFSP cases. However, the proposed algorithm requires large iterations to solve large case problems. In addition, the HMVO algorithm is more effective than GA and ACO in solving EPPFSP problems.

Keywords: Energy-efficient; flow shop; Multi-Verse Optimizer; Algorithm

1. Introduction

In manufacturing, electrical energy becomes an essential resource [1]. The electrical energy needs in the manufacturing sector have continued to increase in recent decades [2]. In Germany, this sector consumes more than forty-seven percent of the total domestic electrical energy [3]. Furthermore, manufacturing companies in China required almost half of the domestic electrical energy [4]. Moreover, electrical energy is generated from fossil fuels in power plants [5, 6]. Therefore, the manufacturing sector must contribute to minimizing this problem. One effective way to solve this issue is energy-efficient scheduling [7]. One of the energy-efficient scheduling issues is in the flow shop problem. This issue is called the Energy-Efficient Permutation Flow Shop Scheduling Problem (EPPFSP) [8]. Flow shop scheduling has job characteristics that are processed in the same order [9-11]. Researchers have published several EPPFSP studies. Several exact, heuristics, and metaheuristics procedures have been proposed. In the exact procedure, the branch and bound procedure were offered by Liu, Zhang, Yang, Chen and Huang [12], and Mixed Integer Linear Programming (MILP) was proposed by Fazli Khalaf and Wang [13]. One of the heuristic procedures proposed was Novel NEH [14]. In addition, Several metaheuristics and hybrid procedures have been proposed, such as ant colony optimization (ACO) [15], Genetic Algorithm (GA) [16], A Modified Immune Clone [17], Hybrid Whale Optimization [18]. The metaheuristic algorithm has high popularity from several procedures proposed in the EPPFSP problem compared to other procedures. One of the interesting



new metaheuristic algorithms is the Multi-Verse Optimizer (MVO) algorithm [19]. This algorithm is inspired by the displacement of the position of the universe. The MVO algorithm has been applied in various engineering fields. However, to the best of our knowledge, the MVO algorithm was never applied in the EEPFSP problem. Therefore, this study proposes an MVO algorithm integrated with a tabu search procedure to solve the EEPFSP problem. We call this algorithm as hybrid MVO (HMVO). In the EEPFSP issue, this research concentrates on reducing energy consumption which concerns a sequence-dependent setup time.

2. Methods

2.1 Assumptions, notations, and mathematical models

One of the scheduling problems is EEPFSP which requires jobs to be completed in the same order on a series of machines. In this EEPFSP problem, this research involves setup time which depends on the sequence job. The assumptions used in this study are: (1) on all l machines, the start time is 0; (2) The setup time for each job on the machine depends on the job sequence; (3) machine finish time is defined as the time when the final work on each machine l is completed. Furthermore, (4) setup time should be separated from processing time, (5) no work should be interrupted. The following is a notation in the problem of minimizing total electricity energy consumption in the EEPFSP problem:

| | |
|-------------|---|
| l | list of machines, $l = 1, 2 \dots q$ |
| k | list of jobs, $k = 1, 2 \dots p$ |
| q | number of machines total |
| p | number of jobs |
| S_k | Setup time k job each machine in the first sequence (hour) |
| $S_{k,k+1}$ | setup time for moving sequence k to $k + 1$ on all machines (hours) |
| $T_{k,l}$ | processing time for a job k to be processed on machines l (hour) |
| P_{el} | index of machine electricity consumption l (watt/hour) |
| I_{el} | electricity consumption index of machine l when idle (watt/hour) |
| S_{el} | electricity consumption Setup index of machine l (watt/hour) |
| $C_{k,l}$ | completion time of job sequence k at on machines l |
| Bl | total busy time of machines l (hour) |
| Tl | completion time of machines l (hour) |
| Sl | total setup time of machines l (hour) |
| Il | total machinery idle time l (hour) |
| TEC | use of total energy (watt) |

Figure 1. Notation in the problem of minimizing total electricity energy consumption in the EEPFSP problem

The mathematical model for the EEPFSP problem is as follows:

$$\text{Goal function } Z_{min} = \min TEC \quad (1)$$

Constraint :

$$C_{1,1} = S_1 + P_{1,1} \quad (2)$$

$$C_{1,l} = \max(C_{1,l-1}, S_1) + P_{1,l}, \quad l = 2 \dots q \quad (3)$$

$$C_{k,1} = C_{k-1,1} + S_{k-1,k} + P_{k,1}, \quad k = 2 \dots p \quad (4)$$

$$C_{k,l} = \max(C_{k,l-1}, S_{k-1,k} + C_{k-1,l}) + P_{k,l}, \quad k = 2 \dots p, l = 2 \dots q \quad (5)$$

$$Bl = \sum_{k=1}^p P_{k,l}, \quad \forall l = 1 \dots q \quad (6)$$

$$Sl = \sum_{k=2}^p S_{k-1,k} + S_1, \quad \forall l = 1..q \quad (7)$$

$$Tl = \max(C_{k,l}), \quad \forall k = 1..p, l = 1..q \quad (8)$$

$$Il = Tl - Bl - Sl, \quad \forall l = 1..q \quad (9)$$

$$TEC = \sum_{l=1}^q (Bl.Pel + Il.Iel + Sl.Sel) \quad (10)$$

The objective function of reducing the energy electricity consumption of the EEPFSP issue is modeled in Equation (1). finish time on the first sequence job on machine 1 is formulated in the Constraints (2). Constraints (3) describes the finish time of the first sequence job on machines 2 to q . The finish time of k sequence jobs on machine 1 is modeled on the Constraints (4). Constraints (5) formulates the finish time of k job sequences on machine l . The busy time of each machine l is shown in Constraint (6). Constraints (7) describe the setup time. The machine completion time l is presented in Constraint (8). Constraint (9) shows the machine idle time l . The objective function TEC formula is presented in Equation (10).

2.2 Proposed Hybrid Multi-Verse Optimizer Algorithm

The Multi-Verse Optimizer (MVO) algorithm is motivated by events in nature, namely the displacement of the position of the universe. This inspiration originates in the theory of the presence of several universes and their interactions via white, black, and wormholes. In the Hybrid Multi-Verse Optimizer (HMVO) algorithm, three main stages are proposed: exploration, exploitation, and improving solutions with tabu search. In the exploration phase, to explore the search space, the MVO algorithm employs the concept of white holes and black holes. The roulette wheel mechanism is applied to the white holes choice and determination based on the normalization inflation rate. This mechanism is modeled in Equation (11). Where, x_j^i denotes the j th parameter on universes i -th, and Ui denotes universes i -th. $NI(Ui)$ is the normalization of the inflation rate universe i -th, and $r1$ indicates a random number [0 1]. x_k^j is the j -th parameter of the k -th universes choose by the roulette wheels mechanism.

$$x_i^j = \begin{cases} x_k^j & r1 < NI(Ui) \\ x_i^j & r1 \geq NI(Ui) \end{cases} \quad (11)$$

In each iteration, 2 MVO parameters must be updated, namely Traveling Distance Rate (TDR) and Wormhole Existence Probability (WEP). These parameters are modeled in equations (12) and (13). Where, l describes the present iteration, L shows the maximum iteration. min indicates the minimum value (0.2), and max describes the maximum value (1). In the TDR parameter, this parameter depends on the P value. The P value is 6, which indicates the exploitation of iterations. MVO algorithm exploitation formula is shown in Equation (14). Where, Lb denotes Lower bound, and Ub is Upper bound. $r2$, $r3$, and $r4$ are random values [0, 1]. In evaluating the fitness universe, this study proposes a large rank value (LRV) procedure to convert the vector position of the universes to job permutations [9-11].

$$WEP = min + l \times \left(\frac{max - min}{L} \right) \quad (12)$$

$$TDR = 1 - \frac{l^{1/P}}{L^{1/P}} \quad (13)$$

$$x_i^j = \begin{cases} \left\{ \begin{array}{l} X_j + TDR \times ((ub_j - lb_j) \times r4 + lb_j) \\ X_i - TDR \times ((ub_i - lb_i) \times r4 + lb_i) \end{array} \right. & r3 < 0,5 \\ x_i^j & r3 \geq 0,5 \end{cases} \quad \begin{matrix} r2 < WEP \\ r2 \geq WEP \end{matrix} \quad (14)$$

In each iteration, the best solution is selected based on the fitness of the universe. Furthermore, it was improved using the Tabu Search Algorithm (TS). The five main stages of the TS algorithm are 1). Solution Representation, 2). Initial Solution based on the best universe in iterations l , 3). Neighborhood Solutions, 4). Tabu List, 5). Termination criteria [20]. Three neighborhood exchange rules are applied in the TS algorithm, such as swap, flip, and slide. Swapping two sequences is called as Swap rule. The Flip rule is carried out by reversing the order of the jobs. Further, shifting the order is referred to as a slide rule. Flip and swap in l iterations recur $p(p-1)/2$. Furthermore, the slide in iteration l recur p^2 . The pseudocode of the proposed HMVO procedure demonstrates in algorithm 1.

```

Generate random universe (U)
Initialize TDR, WER, and Best fitness universes
while the final iteration is not met
    Apply LRV to convert position universes to job permutation
    Examine the fitness of all universes based on Equation (1)-(10)
    for each universe indexed by i
        Update TDR and WEP based on equation (12) and (13)
        For Black hole index = i;
            for each object index by j
                Exploration Phase
                r1 = Random([0, 1]);
                Apply equation (11)
                Exploitation phases
                r2 = Random([0, 1])
                Apply equation (14)
            end For
        end For
    Improve solution in each iteration using tabu search
end while

```

Figure 2. Pseudocode Hybrid Multi-Verse Optimizier

2.3 Experiments

This study utilized Tk, l data from the research of Carlier [21] and Reeves [22]. The list of problems can be seen in table 1. Six cases were used with three data categories (small, medium, and large). Sk and $S_{k,k+1}$ data were generated from random numbers [1 10]. Pel , Iel , and Sel data were also randomly generated with values [5 10], [1 2], and [1 3], respectively. This EEPFSP experiment was conducted on 100 universes and two iteration variations (100 and 200). Each experiment was recorded to test the effect of TEC, energy setup, process energy, and energy idle. The HMVO algorithm was also compared with the ACO [15], GA [16] algorithm with 200 iteration parameters and a population of 100. This study was run using Matlab R2014a software on Windows 10 Intel (R) Core (TM) i5-4210U CPU @ 1.70. GHz 64-bit 4GB.

Table 1. EEPFSP problem case

| Problem case | Family case | Job | Machine | Refer from |
|--------------|-------------|-----|---------|--------------|
| Case 1 7/7 | Small | 7 | 7 | Carlier [21] |
| Case 2 8/8 | Small | 8 | 8 | Carlier [21] |
| Case 3 20/10 | Medium | 20 | 10 | Reeves [22] |
| Case 4 20/5 | Medium | 20 | 5 | Reeves [22] |
| Case 5 75/20 | Large | 75 | 20 | Reeves [22] |
| Case 6 75/20 | Large | 75 | 20 | Reeves [22] |

3. Result and Discussions

The outcome of the experiment on the influence of iteration on electrical energy consumption are demonstrated in table 2. It shows that increasing iteration affects electricity energy consumption in the large case. However, increasing iterations did not affect the small and medium cases. These results indicate that solving small and medium cases requires low iterations. However, for the large case, the solution requires significant iterations. Other findings show that total energy consumption is influenced by setup and idle electricity energy consumption. In addition, the processing electricity energy consumption is fixed. Therefore, setup time and machine idle time need to be a concern in solving EEPFSP issues. The results of the comparison of the HMVO algorithm with ACO and GA are shown in Figure 1. It shows that in the small case, the three algorithms provide a similar result. Unfortunately, in medium and large, the HMVO algorithm provides a better solution than the GA and ACO algorithms. This research shows that the HMVO procedure is superior to the GA and ACO procedure for solving the EEPFSP problem.

Table 2. HMVO Experiment Results (watt)

| Case | TEC | | Energy setup | | Energy Proses | | Energy Idle | |
|--------|-----------|--------|--------------|-------|---------------|--------|-------------|-------|
| | Iteration | | Iteration | | Iteration | | Iteration | |
| | 100 | 200 | 100 | 200 | 100 | 200 | 100 | 200 |
| Case 1 | 97380 | 97380 | 364 | 364 | 75094 | 75094 | 21922 | 21922 |
| Case 2 | 145351 | 145351 | 615 | 615 | 108777 | 108777 | 35959 | 35959 |
| Case 3 | 39053 | 39053 | 1320 | 1320 | 32256 | 32256 | 5477 | 5477 |
| Case 4 | 21220 | 21220 | 522 | 522 | 19206 | 19206 | 1492 | 1492 |
| Case 5 | 258465 | 258256 | 8964 | 10008 | 218277 | 218277 | 31224 | 29971 |
| Case 6 | 302922 | 303264 | 12831 | 13348 | 252507 | 252507 | 37584 | 37409 |

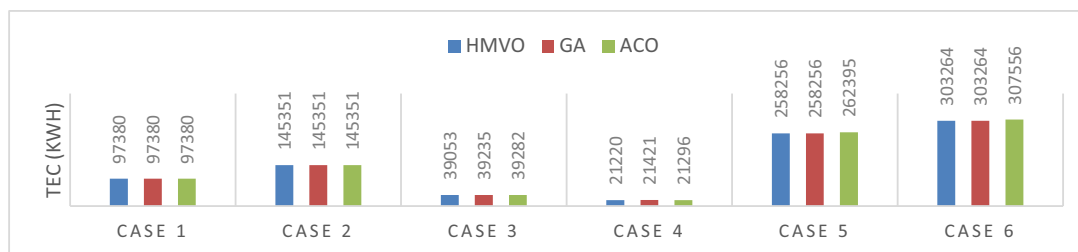


Figure 3. The results of the comparison of the HMVO algorithm with ACO and GA

4. Conclusion

This research proposes the HMVO procedure to solve the EEPFSP problem. Six cases were presented to test the effect of iteration on energy consumption. The results show that large iterations are effective for solving EEPFSP problems on large jobs. In addition, the HMVO algorithm provides a better solution than the GA and ACO algorithms. However, this study ignores the electricity tariffs that are generally used in the actual case. Therefore, in future research, it is necessary to consider energy tariffs in solving the EEPFSP problem.

References

- [1] Jabari A N A A K and Hasan A 2021 Energy-Aware Scheduling in Hybrid Flow Shop using Firefly Algorithm *Jurnal Teknik Industri* **22** 18-30
- [2] Utama D M, Widodo D S, Wicaksono W and Ardiansyah L R 2019 A new hybrid metaheuristics algorithm for minimizing energy consumption in the flow shop scheduling problem *International Journal of Technology* **10** 320-31

- [3] Dai M, Tang D, Giret A, Salido M A and Li W D 2013 Energy-efficient scheduling for a flexible flow shop using an improved genetic-simulated annealing algorithm *Robotics and Computer-Integrated Manufacturing* **29** 418-29
- [4] Liu Y, Dong H, Lohse N, Petrovic S and Gindy N 2014 An investigation into minimising total energy consumption and total weighted tardiness in job shops *Journal of Cleaner Production* **65** 87-96
- [5] Utama D M 2019 An effective hybrid sine cosine algorithm to minimize carbon emission on flow-shop scheduling sequence dependent setup *Jurnal Teknik Industri* **20** 62-72
- [6] Utama D M, Baroto T and Widodo D S 2020 Energy-Efficient Flow Shop Scheduling Using Hybrid Grasshopper Algorithm Optimization *Jurnal Ilmiah Teknik Industri* **19** 30-8
- [7] Kurniawan B 2020 Mathematical Models of Energy-Conscious Bi-Objective Unrelated Parallel Machine Scheduling *Jurnal Teknik Industri* **21** 115-25
- [8] Utama D M and Widodo D S 2021 An energy-efficient flow shop scheduling using hybrid Harris hawks optimization *Bulletin of Electrical Engineering and Informatics* **10** 1154-63
- [9] Utama D 2021 Minimizing Number of Tardy Jobs in Flow Shop Scheduling Using A Hybrid Whale Optimization Algorithm. In: *Journal of Physics: Conference Series: IOP Publishing*) p 012017
- [10] Utama D M, Widodo D S, Ibrahim M F and Dewi S K 2020 An effective hybrid ant lion algorithm to minimize mean tardiness on permutation flow shop scheduling problem *International Journal of Advances in Intelligent Informatics* **6** 23-35
- [11] Widodo D S and Utama D M 2020 The Hybrid Ant Lion Optimization Flow Shop Scheduling Problem for Minimizing Completion Time. In: *Journal of Physics: Conference Series: IOP Publishing*) p 022097
- [12] Liu G-S, Zhang B-X, Yang H-D, Chen X and Huang G Q 2013 A branch-and-bound algorithm for minimizing the energy consumption in the PFS problem *Mathematical Problems in Engineering* **2013**
- [13] Fazli Khalaf A and Wang Y 2018 Energy-cost-aware flow shop scheduling considering intermittent renewables, energy storage, and real-time electricity pricing *International Journal of Energy Research* **42** 3928-42
- [14] Liu G-S, Li J-J and Tang Y-S 2018 Minimizing total idle energy consumption in the permutation flow shop scheduling problem *Asia-Pacific Journal of Operational Research* **35** 1850041
- [15] Tuo L, Dai L and Chen X 2014 Scheduling of Discrete Manufacturing Process for Energy Saving. In: *Applied Mechanics and Materials: Trans Tech Publ*) pp 4248-54
- [16] Luo J, Fujimura S, El Baz D and Plazolles B 2019 GPU based parallel genetic algorithm for solving an energy efficient dynamic flexible flow shop scheduling problem *Journal of Parallel and Distributed Computing* **133** 244-57
- [17] Yang Y and Qi W Y 2018 A modified immune clone algorithm for energy-saving scheduling in permutation flow shop. In: *Journal of Physics: Conference Series: IOP Publishing*) p 022009
- [18] Utama D M, Widodo D S, Ibrahim M F, Hidayat K, Baroto T and Yurifah A 2020 The hybrid whale optimization algorithm: A new metaheuristic algorithm for energy-efficient on flow shop with dependent sequence setup. In: *Journal of Physics: Conference Series: IOP Publishing*) p 022094
- [19] Mirjalili S, Mirjalili S M and Hatamlou A 2016 Multi-verse optimizer: a nature-inspired algorithm for global optimization *Neural Computing and Applications* **27** 495-513
- [20] Ben-Daya M and Al-Fawzan M 1998 A tabu search approach for the flow shop scheduling problem *European journal of operational research* **109** 88-95
- [21] Carlier J 1978 Ordonnancements à contraintes disjonctives *RAIRO-Oper. Res.* **12** 333-50
- [22] Reeves C R 1995 A genetic algorithm for flowshop sequencing *Computers & Operations Research* **22** 5-13