

**FOLDING MECHANISM MODIFICATION OF THE CLSU-DEVELOPED  
MOBILE SOLAR-POWERED PUMP IRRIGATION SYSTEM (MSPIS)**

**JUVIE ANNE M. LINGAS**

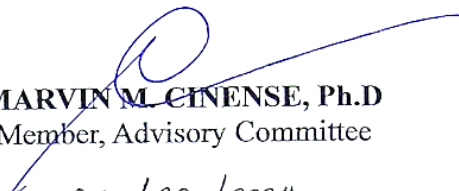
An Undergraduate Thesis Submitted to the Faculty of the Department of Agricultural  
and Biosystems Engineering, College of Engineering, Central Luzon State  
University, Science City of Muñoz, Nueva Ecija, Philippines  
in Partial Fulfillment of the Requirements  
for the Degree of

**BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS  
ENGINEERING  
(AB Machinery and Power Engineering)**


**JULY 2024**

**ACCEPTANCE SHEET**

This undergraduate thesis entitled **“FOLDING MECHANISM MODIFICATION OF THE CLSU-DEVELOPED MOBILE SOLAR-POWERED PUMP IRRIGATION SYSTEM (MSPIS)”**, prepared and submitted by **JUVIE ANNE M. LINGAS** in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (MAJOR IN AB MACHINERY AND POWER ENGINEERING)**, is hereby accepted:

  
**MARVIN M. CINENSE, Ph.D**  
Member, Advisory Committee

06 / 28 / 2024  
Date Signed

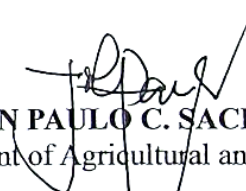
  
**WENDY C. MATEO, Ph.D**  
Member, Advisory Committee

06 / 25 / 2024  
Date Signed

  
**JONATHAN V. FABULA, Ph.D**  
Chair, Advisory Committee

06 / 25 / 2024  
Date Signed

Accepted as partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (MAJOR IN AB MACHINERY AND POWER ENGINEERING)**:

  
**JOHN PAULO C. SACDALAN, Ph.D**  
Head, Department of Agricultural and Biosystems Engineering

06 / 28 / 2024  
Date Signed

  
**ROY SEARCA JOSE P. DELA CRUZ, Ph.D**  
Acting Dean, College of Engineering

06 / 28 / 2024  
Date Signed

## **BIOGRAPHICAL SKETCH**

Juvie Anne Mueña Lingas was born on November 02, 2002, at Cabanatuan City, Nueva Ecija. She is the eldest of the three children of Mr. Leonardo A. Lingas Jr. and Mrs. Virgie M. Lingas, who have been there since Day One of her journey. Their unwavering support and belief in her abilities constantly motivated her.

From an early stage in her development, Juvie Anne had a remarkable curiosity and an unwavering determination to conquer her aspirations. In the early stages of her life, she was consumed by an insatiable hunger for knowledge, a never-ending desire to go into the depths of diverse fields of interest. She started her academic journey at the age of three (3) as a Day Care Center student at their barangay. She finished her primary education in 2014 at San Alejandro Elementary School, Quezon, Nueva Ecija; then her secondary education at Dominican High School, Sto. Domingo, Nueva Ecija.

Juvie Anne is currently an undergraduate student at Central Luzon State University (CLSU), taking up Agricultural and Biosystems Engineering. Her strong motivation to acquire knowledge propelled her to achieve exceptional results in her academic endeavors, garnering her the respect of her peers and teachers.

**JUVIE ANNE M. LINGAS**

## ACKNOWLEDGMENT

The author would like to extend her heartfelt appreciation to the individuals who generously contributed their time and support to the completion of this study.

To Sir Jonathan V. Fabula, the assigned adviser for the author for his time and commitment. His feedback and support greatly enhanced the quality of this thesis, his time for checking the thesis paper carefully, and his patience and understanding have been a source of motivation during challenging times.

To Sir Marvin M. Cinense and Ma'am Wendy C. Mateo, for being a member of the author's thesis committee. Their unwavering support, time, suggestions, and invaluable guidance throughout this entire process.

To Sir Ruel G. Peneyra, a consultant of the author. His invaluable guidance, generous time, insightful ideas, valuable advice, and unwavering support throughout the completion of this study. The valuable input provided by him significantly contributed to the enhancement of this study.

To Prof. Roy Searca Jose P. Dela Cruz, the Acting Dean, and all the faculty members and staff members of the College of Engineering for their contributions to the author's education and the development of knowledge and experience.

To the friends of the author, for extending their unlimited encouragement, time, and support throughout this study. To the author's thesis partners, the people who made the author feel that she was not alone in this study.

To the respected parents of the author, Mr. Leonardo A. Lingas Jr., and Mrs. Virgie M. Lingas. Their constant support, guidance, words of wisdom, financial assistance, and

inspiration were invaluable throughout this incredible and expensive journey. The author owes her achievements to the solid support and motivation they received.

Above all, the author would like to thank God Almighty for giving her the strength, knowledge, ability, and opportunity to undertake this study. Without His blessings, this success of this study would not have been possible.

## TABLE OF CONTENTS

	<b>PAGE</b>
BIOGRAPHICAL SKETCH	iii
ACKNOWLEDGMENT	iv
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF APPENDIX TABLES	xi
LIST OF APPENDIX FIGURES	xiii
ABSTRACT	xv
INTRODUCTION	1
Background of the Study	1
Statement of the Problem	2
Objectives of the Study	4
Significance of the Study	4
Scope and Limitation of the Study	5
Time and Place of the Study	6
REVIEW OF RELATED LITERATURE	7
Renewable Energy in the Philippines	7
Irrigation System in the Philippines	8
Water Sources	9
Ground Water	10
Deep-well	11
Climate Change	12
Solar-Powered Pump Technology	13
Solar Panel	13
Mobile Irrigation Systems	14
Rack and Pinion	15
METHODOLOGY	16

Conceptualization of the Study	16
Modification of the Folding Mechanism of the CLSU Mobile Solar-powered Pump Irrigation System (MPSIS)	18
Principles of Operation	19
Description of Machine Parts	20
Solar Panel/Frame Support	20
Rack and Pinion	21
Rotating Mechanism	22
Shaft	23
Sliding Mechanism	24
Design Consideration	25
Statistical Analysis	27
Assumption Checking	27
Data Gathered	29
Time of Operation Under the Age Parameter	30
Time of Operation Under the Height Parameter	31
Time of Operation Under the Sex Parameter	31
Cost Analysis	32
Fixed cost	33
Depreciation	33
Interest on Investment	34
Variable cost	34
Repair and Maintenance	35
Labor Cost	35
RESULTS AND DISCUSSION	37
Preliminary Testing	38
Final Adjustment	40
Performance Evaluation of the Folding Mechanism for CLSU-developed MPSIS	41
Performance Evaluation	42
Assembly Time	43
Folding Time	44
Operation Time	46
Weighted Mean based on Evaluation Form	49
Cost Analysis	49
SUMMARY, CONCLUSION, AND RECOMMENDATIONS	54

Summary	54
Conclusion	56
Recommendations	57
LITERATURE CITED	58
APPENDICES	61
APPENDIX TABLE	62
APPENDIX FIGURES	82
Technical Plan	99

## LIST OF TABLES

TABLE		PAGE
1	Factors consideration in designing a Folding Mechanism for CLSU-developed MSPIS	26
2	Preliminary testing of the folding mechanism of MSPIS	38
3	Resulted Weighted Mean	49
4	Cost analysis of the modified folding mechanism of the CLSU-developed MSPIS	53

## LIST OF FIGURES

FIGURE		PAGE
1	Conceptual Framework of the Study	17
2	Design of the modified folding mechanism for CLSU-developed MSPIS	18
3	Solar Panel/Frame Support	20
4	Rack and Pinion	21
5	Rotating Mechanism	22
6	Shafting	23
7	Sliding Mechanism	24
8	Experimental Layout	29
9	Folding Mechanism for the CLSU-Developed Mobile Solar-powered Pump Irrigation System (MSPIS)	37
10	Placing stopper in the slider	39
11	Pivot for the Solar Panel with a single hole	40
12	Bolted components for the machine	41
13	Assembly time with the three replications	43
14	Folding time with the three replications	45
15	Operation time with the three replications	47

## LIST OF APPENDIX TABLES

APPENDIX TABLE	PAGE
1 Components and specification of the folding mechanism of MSPIS.	62
2 Raw data gathered from testing the machine by measuring the assemble time of the solar panels	63
3 Raw data gathered from testing the machine by measuring the folding time of the solar panels	65
4 Raw data gathered from testing the machine by measuring the operation time of the solar panels	67
5 Assumption checking for assembly time	68
6 Assumption checking for folding time	68
7 Assumption checking for operation time	69
8 ANOVA - assembly time (sec)	69
9 Descriptive statistics (mean and standard deviation) of assembly time across different factors	70
10 Assembly time in operation (sec)	71
11 ANOVA - folding time (sec)	71
12 Descriptive statistics (mean and standard deviation) of folding time across different factors	72
13 Folding time in operation (sec)	73
14 ANOVA - OPERATION TIME (sec)	73
15 Descriptive statistics (mean and standard deviation) of operation time across different factors	74
16 Operation time (sec)	75
17 Gathered raw data for weighted mean	76

APPENDIX TABLE	PAGE
18 Likert scale interpretation	77
19 Cost of Materials	78
20 Direct Labor Cost	79
21 Electric Bills	79
22 Total Fixed Cost	80
23 Total Variable Cost	80
24 Interest on Investment Cost	80
25 Depreciation	80
26 Oil and lubricant Cost	81
27 Labor Cost for Operation in Field	81
28 Repair and Maintenance Cost	81

## LIST OF APPENDIX FIGURES

APPENDIX FIGURE	PAGE
1 Procurement of Materials	82
2 Materials Preparation	82
3 Main Frame Composition	83
4 Finishing the Main Frame Component	83
5 Composition of a Mechanism Enclosure	84
6 Solar Panel Support	84
7 Final Main Frame of the Machine	85
8 Composition of Rack and Pinion Mechanism	85
9 Final Mechanism of the Machine	86
10 Placement of Main Mechanism	86
11 Roller Bearing	87
12 Transporting of Solar Panel from PREDICT	87
13 Mounting of Solar Panels	88
14 Pre-Testing of the Machine	88
15 Screening of Participants Needed to Test the Machine	89
16 Data Gathering and Final Testing of Machine	89
17 Collecting of Evaluation Form	90
18 Transferring of Machine to PREDICT	90
19 Assembling of Machine at PREDICT	91
20 Machine Testing at PREDICT	91

APPENDIX FIGURE	PAGE
21 Folding Mechanism of CLSU-developed MSPIS	92
22 Folding Orientation of the Machine	92
23 Sample (A1B1C2) Evaluation Form after Testing the Machine	93
24 Sample (A3B2C1) Evaluation Form after Testing the Machine	94
25 Sample (A1B1C1) Evaluation Form after Testing the Machine	95
26 Testing of Folding Mechanism of CLSU-developed MSPIS in PREDICt	96
27 Evaluation of Folding Mechanism of CLSU-developed MSPIS in PREDIsCt	96
28 Isometric View of the Design	97
29 Side View of the Design	98
30 Top View of the Design	98

## ABSTRACT

**LINGAS, JUVIE ANNE M.** Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija. JULY 2024, **FOLDING MECHANISM MODIFICATION OF THE CLSU-DEVELOPED MOBILE SOLAR-POWERED PUMP IRRIGATION SYSTEM (MSPIS).**

Adviser: JONATHAN V. FABULA, PhD.

The increasing need for sustainable irrigation solutions in remote agricultural areas has driven the development of Mobile Solar-Powered Pump Irrigation Systems (MSPIS). Although there are clear advantages to using these systems, the process of assembling and folding the solar panels is time-consuming and labor-intensive.

This study was conducted to minimize the time and labor intensity needed to setup the system's solar panel on field. The performance evaluation of the folding mechanism was done in terms of measuring the time consumed in operating the system. The treatments were laid out following a completely randomized design (CRD). Three different factors were considered in gathering the data needed for this study. A set of ranges was distributed to the factors A, B, and C. Factor A represents the age range from 15-31 (A1), 32-48 (A2), and 49-65 (A3). Factor B represents the height range from 149-159cm (B1), 160-170cm (B2), and 171-181cm (B3). Factor C represents the person's sex, male is represented by C1, and female is represented by C2. Combining the three factors resulted in 18 combinations that had three replications, for a total of 54 samples.

The results of this study, which used a factorial ANOVA, show that there was no significant difference between the three factors in terms of assembly, folding, and operation time. A3B1C2 had the longest mean time of assembly, reported at 38.19 seconds, while

A2B2C1 had the shortest mean time of assembly, reported at 32.5 seconds. A1B2C2 has the longest mean time of folding reported at 31.5 sec, while A2B2C1 has the shortest mean time of folding at 24.16 sec. A1B2C2 (69.08 sec) has the longest time consumed, while the combination A2B2C1 (56.58 sec) has the shortest time consumed for the whole operation.

The modified design in this study minimized the time in using the machine and can be easily operated by a single person. Where the assembly time can last up to almost 40 seconds and a folding process takes a maximum of 35 seconds. However, it is recommended to use two people in operating the machine for easier and faster operation. Moreover, observation suggests that adding another pivot arm to connect the two solar panel supports on both sides of the machine to prevent the jamming of the roller bearing of the solar panel frame.

Keyword: Mobile Solar-Powered Pump Irrigation Systems (MSPIS); Assembly; Folding; Operation; Time

## LITERATURE CITED

- Alonazi, M., Beloff, N., & White, M. (2019). Exploring Determinants of M-Government Services: A Study from the Citizens' Perspective in Saudi Arabia. *Annals of Computer Science and Information Systems*. <https://doi.org/10.15439/2019f75>
- Bencalo, C. E., Cruz, R. D. dela, Violago, D. R., Magtalas, M. B., Aquino, C. S., & Santos, M. D. (2022). Cost benefit Analysis Between Solar-Powered and Diesel Fuel-Fed Pumps of the National Irrigation Administration Upper Pampanga River Integrated Irrigation Systems. *International Journal of Advanced Engineering, Management and Science*, 8(2), 17–21. <https://doi.org/10.22161/ijaems.82.2>
- Bolanos, J. A. C., Ortíz, W., & Bhandari, R. (2014). *Techno-economic feasibility study of solar and wind-based irrigation systems in northern Colombia. Proceedings of the 4th World Sustainability Forum*. <https://doi.org/10.3390/wsf-4-e012>
- Bostock, B., & Jankowicz, M. (2023). Ranked: The countries with the shortest people in the world. *Business Insider*. <https://www.businessinsider.com/shortest-people-in-world-by-country-2019-6>
- Bouchard, C., Malina, R., & Pérusse, L. (1997). Genetics of fitness and physical performance. Google Books. [https://books.google.com.ph/books?id=APIPuCuBU00C&printsec=frontcover&source=gbg\\_summary\\_r&cad=0#v=onepage&q&f=false](https://books.google.com.ph/books?id=APIPuCuBU00C&printsec=frontcover&source=gbg_summary_r&cad=0#v=onepage&q&f=false)
- Briones, R.M. (2017). *Characterization of agricultural workers in the Philippines, PIDS Discussion Paper Series, No. 2017-31*, Philippine Institute for Development Studies (PIDS), Quezon City <https://www.econstor.eu/handle/10419/173608>
- BWC-DOLE - RULE II, BOOK VI OF THE RULES IMPLEMENTING THE LABOR CODE (RETIREMENT BENEFITS FOR EMPLOYEES IN THE PRIVATE SECTOR) - Supreme Court E-Library. (n.d.). <https://elibrary.judiciary.gov.ph/thebookshelf/showdocs/10/52124>
- Climate Change in the Philippines. (n.d.). PAGASA. <https://www.pagasa.dost.gov.ph/information/climate-change-in-the-philippines>
- Davis, R., Johnson, A., & Smith, J., (2018). Design and implementation of a chain and sprocket folding mechanism for a foldable table. *Journal of Engineering Design*, 23(4), 267-279.
- DOLE DEPARTMENT ORDER NO. 18 - RULES AND REGULATIONS IMPLEMENTING REPUBLIC ACT NO. 7658 - Supreme Court E-Library. (n.d.). <https://elibrary.judiciary.gov.ph/thebookshelf/showdocs/10/74561>

- Du, T., Kang, S., Zhang, J., & Davies, W. J. (2015). Deficit irrigation and sustainable water-resource strategies in agriculture for china's food security. *Journal of Experimental Botany*, 66(8), 2253-2269. <https://doi.org/10.1093/jxb/erv034>
- Foster, S. (2020). Global Policy Overview of Groundwater in Urban Development—A tale of 10 cities! *Water*, 12(2), 456. <https://doi.org/10.3390/w12020456>
- Garcia, B. C. B., Dimasupil, M. A. Z., Vital, P. G., Widmer, K. W., & Rivera, W. L. (2015). Fecal contamination in irrigation water and microbial quality of vegetable primary production in urban farms of metro manila, philippines. *Journal of Environmental Science and Health, Part B*, 50(10), 734-743. <https://doi.org/10.1080/03601234.2015.1048107>
- J. Burney, L. Woltering, M. Burke, R. Naylor, D. Pasternak, Solar-powered drip irrigation enhances food security in the Sudano-Sahel, *Proc. Natl. Acad. Sci. U.S. A* 107 (5) (2010) 1848–1853.
- Kim, Y., & Lee, S. (2020). Investigation of folding mechanism using chain and sprocket for collapsible chair design. *International Journal of Advanced Manufacturing Technology*, 108(1-2), 9-18.
- Maraseni, T., Mushtaq, S., Hafeez, M., & Maroulis, J. (2010). Greenhouse gas implications of water reuse in the upper pumpanga river integrated irrigation system, philippines. *Agricultural Water Management*, 97(3), 382-388. <https://doi.org/10.1016/j.agwat.2009.10.007>
- Rivera, D. (2023). CLSU to integrate agri-voltaic system in farm production. *Philstar.com*. <https://www.philstar.com/business/2023/08/06/2286491/clsu-integrate-agri-voltaic-system-farm-production>
- Shaker, L. M., Al-Amiery, A. A., Hanoon, M. M., Al-Azzawi, W. K., & Kadhum, A. A. H. (2024). Examining the influence of thermal effects on solar cells: a comprehensive review. *Sustainable Energy Research*, 11(1). <https://doi.org/10.1186/s40807-024-00100-8>
- Mishra, S. (2020) *Low-cost, On-demand, Pay-as-you-go, Solar Powered Irrigation Service using Battery-operated EVs in rural agrarian regions of North India Final Report Powering Agriculture Innovator (PAEGC)*. [https://pdf.usaid.gov/pdf\\_docs/PA00Z2Q6.pdf](https://pdf.usaid.gov/pdf_docs/PA00Z2Q6.pdf)
- Molden, D. (2013). Water for food water for life. <https://doi.org/10.4324/9781849773799>

- Pimentel, D., Houser, J., Preiss, E., White, O., Fang, H., Mesnick, L., ... Alpert, S. (1997). *Water Resources: Agriculture, the Environment, and Society*. *BioScience*, 47(2), 97–106. doi:10.2307/1313020
- Smith, P., Martino, D., Cai, Z., Howden, M., Rypdal, K., Wa Githendu, M., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., Rice, C., Scholes, B., & Sirotenko, O. (2007). *8 Agriculture*. In *Climate Change*. Intergovernmental Panel on Climate Change (IPCC). <https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg3-chapter8-1.pdf>
- Solar Energy | A Student's Guide to Global Climate Change | US EPA*. (2017). Environmental Protection Energy. <https://archive.epa.gov/climatechange/kids/solutions/technologies/solar.html>
- The Editors of Encyclopaedia Britannica. (2024, May 9). Old age | Challenges, Benefits & Lifestyle Changes. Encyclopedia Britannica. <https://www.britannica.com/science/old-age>
- Toga, M. T. (2020). Solar powered irrigation for sustainable development and its risk in ethiopia. <https://doi.org/10.21203/rs.3.rs-75607/v1>
- Wanyama, J., Soddo, P., Nakawuka, P., Tumutegereize, P., Bwambale, E., Oluk, I., Mutumba, W., & Komakech, A. J. (2023). Development of a solar powered smart irrigation control system Kit. *Smart Agricultural Technology*, 5. <https://doi.org/10.1016/j.atech.2023.100273>
- Wazed, S. M., Hughes, B. R., O'Connor, D., & Calautit, J. K. (2018). A review of sustainable solar irrigation systems for sub-saharan africa. *Renewable and Sustainable Energy Reviews*, 81, 1206-1225. <https://doi.org/10.1016/j.rser.2017.08.039>
- Vital, P. G., Zara, E. S., Paraoan, C. E. M., Dimasupil, M. A. Z., Abello, J. J. M., Santos, I. T. G., ... & Rivera, W. L. (2018). Antibiotic resistance and extended-spectrum beta-lactamase production of escherichia coli isolated from irrigation waters in selected urban farms in metro manila, philippines. *Water*, 10(5), 548. <https://doi.org/10.3390/w10050548>