



Faculty of Engineering

**Iterative Simulation-Based Design of a Multi Input Controller for a
Hybrid Renewable Energy System**

Abdullahi Inusa

Doctor of Philosophy

2021

Iterative Simulation-Based Design of a Multi Input Controller for a Hybrid
Renewable Energy System

Abdullahi Inusa

A thesis submitted

In fulfillment of the requirements for the degree of Doctor of Philosophy

(Electrical Engineering)

Faculty of Engineering

UNIVERSITI MALAYSIA SARAWAK

2021

DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

.....

Signature

Name: Abdullahi Inusa

Matric No.: 15010115

Faculty of Engineering

Universiti Malaysia Sarawak

Date:

ACKNOWLEDGEMENT

Every life endeavour comes with its individual motivations; Allahamdulillah, thanking Allah (SWT) for his infinite mercies for making it possible for me to witness the completion of my PhD pursuit. I also put forth many prayers that may it be beneficial to entire humanity, my family, and self by Allah's grace. Aamiin ya Rabbil Alamin.

I sincerely appreciated my supervisor's efforts in diverse form, Associate Professor Dr Thelaha bin Hj Masri who encouraged and supported me in different ramifications throughout the study period at Universiti Malaysia Sarawak. His expertise in the study remains with me as an indelible guided footstep to emulate. Similarly, I thank my co-supervisor Professor Dr Wan Azlan Wan Zainal Abidin for his enormous support and encouragements at hard times. Many thanks go to my family that included wife Hajiya Hannatu Musa, children Dr Abba A. Yunusa MBBS, Aisha A. Yunusa ICAN, Muhammad A. Yunusa student Engineer, and Ibrahim A. Yunusa who have been considerate during the study period for living on very meagre resources as when tuition and rent fee becomes due. I also thank the Department, Faculty and the Universiti Malaysia Sarawak for their wonderful supports on their humanly resourcefulness.

I appreciated my colleagues and good friends like Mr. Melvin who translate abstract to Bahasa Malaysia, Dr Salisu M Lawan, Dr Saidu Adamu Abubakar, the university that contributed in many ways toward the successful completion of this thesis. Thanks a lot. Jazakumullahu Khair.

ABSTRACT

Sustainable energy supply is a priority need for socioeconomic and entrepreneurial development of communities in remote areas. Especially, in a developing country like Malaysia, providing sustainable energy to these areas has become a challenging task for the government. From past records, a micro-hydro plant hardly works for more than one year continuously without having problems like stalling or breakdowns due to ecological / technical problems. Generators fuel has been very expensive and further away from remote villagers. The enhancement of single source standalone renewable energy to hybrid structure will provide alternative power supply as standby to the consumer load. The one important component to this method is the automated control units that could monitor all resources' conditions and decides which source of power supply is on standby. The Micro-Hydro is the main source and solar photovoltaic with the other energy resources are at standby. With that, in this study, a design of an iterative sequential controller for multiple inputs, single output power system was considered and proposed. Micro hydro and solar photovoltaic renewable energy, energy storage and Utility grid are used as alternative standby resource, determined by priority. The projected concept is interactive user friendly, flexible, visually analytical for remote standalone hybrid renewable energy station regulator. The design apply algorithm to implement object oriented finite-state machines model constructed from Simulink to obtain multiple-input single-output profile. The model-depicted curves of sequential transition trajectory contour, logic truth table, etc. in the practical selection for project work. The hybrid design of controller improved the standalone renewable energy system sustainability and alleviate other challenges at lower cost.

Keywords: Hybrid renewable energy resource, iterative simulation-based, design Sustainability, modelling, Finite-state machines

Reka Bentuk Berasaskan Simulasi Iteratif Pengawal Hibrid untuk Sistem Tenaga Boleh Diperbaharui Hibrid

ABSTRAK

Bekalan tenaga lestari adalah keperluan utama bagi pembangunan sosioekonomi dan keusahawanan masyarakat di kawasan terpencil, terutama di negara membangun seperti Malaysia. Menyediakan sistem tenaga lestari ke kawasan-kawasan ini telah menjadi tugas yang mencabar bagi pemerintah. Dari kajian lalu, loji hidro mikro yang dipasang di kawasan-kawasan tertentu telah didapati tidak berfungsi selepas lebih dari satu tahun disebabkan mengalami masalah dan kerosakan berpunca daripada faktor-faktor ekologi dan teknikal. Bahan bakar untuk sistem janakuasa elektrik (generator) pula sangat mahal dan terletak jauh daripada penduduk kampung yang tinggal di kawasan terpencil. Dengan itu, pengenalan kepada sistem tenaga boleh diperbaharui berstruktur hibrid akan menyediakan bekalan kuasa alternatif sebagai penyelesaian kepada pengguna. Satu komponen penting dalam kaedah ini adalah unit kawalan automatik yang dapat memantau keadaan semua sumber dan memutuskan pilihan sumber bekalan kuasa yang sesuai untuk pengguna. Dalam kajian ini, sistem tenaga hidro mikro diambil sebagai sumber utama selain sistem tenaga solar dan sumber tenaga lain yang lumrah digunakan. Dengan itu, reka bentuk pengawal urutan berulang untuk pelbagai input dengan, sistem kuasa output tunggal diperkenal dan dicadangkan. Tenaga elektrik dari sistem hidro mikro, sistem solar, sistem kincir angin dan grid utiliti disediakan sebagai sumber siap sedia alternatif, manakala pemilihannya ditentukan keutamaannya dari konsep yang diperkenalkan, supaya ianya lebih mesra pengguna dari sudut interaktif, fleksibel disertai dengan analisis visual untuk pengatur stesen tenaga boleh diperbaharui hibrid secara mandiri. Reka bentuk model yang dicadangkan menerapkan algoritma model mesin berorientasikan objek yang dibina dari

Simulink untuk mendapatkan profil output tunggal berbilang input. Lengkung model yang dihasilkan dari kontur lintasan peralihan berurutan, jadual kebenaran logik, dan lain-lain dalam pemilihan praktikal untuk kerja projek, dikaji secara terperinci. Reka bentuk pengawal hibrid ini meningkatkan kesinambungan sistem tenaga boleh diperbaharui secara mandiri dan mengurangkan kos operasi secara keseluruhan.

Kata kunci: *Sumber tenaga boleh diperbaharui hibrid, reka bentuk berasaskan simulasi berulang, kelestarian, pemodelan dan mesin finite-state*

TABLE OF CONTENTS

	Page
DECLARATION	i
ACKNOWLEDGEMENT	ii
ABSTRACT	iii
<i>ABSTRAK</i>	v
TABLE OF CONTENTS	vii
LIST OF TABLES	xii
LIST OF FIGURES	xiii
LIST OF ABBREVIATIONS	xviii
CHAPTER 1: INTRODUCTION	1
1.1 Introduction	1
1.2 Project Preview	8
1.3 Statement of Problem / Hypothesis	9
1.3.1 Statement of Problem	9
1.3.2 Hypothesis	11
1.4 Aim and Objectives of the Study	11
1.5 Scope of Work	12
1.6 Thesis Structure	14
CHAPTER 2: LITERATURE REVIEW	15
2.1 Introduction	15
2.2 Techniques and Design of HRES	18
2.2.1 Hybrid Renewable Energy System (HRES)	20
2.2.2 Hybrid Renewable Energy Resources	26

2.3	Development of Hybrid RE models	26
2.3.1	Hybrid Solar Photovoltaic (SPV) Power System	30
2.3.2	Solar Photovoltaic (PV) Energy Harvester Characteristics	32
2.3.3	SPV Socioeconomic / Physical / Technological Features	37
2.3.4	Energy Conditioner System (ECS) Characteristics	40
2.3.5	Programmable Logic Controller (PLC) and DC-AC Inverter	40
2.3.6	Maximum Power Point Tracking (MPPT) Charge Controller Features	43
2.4	Hybrid Energy Storage System (HESS)	43
2.4.1	Hybrid Energy Storage System (HESS) Features	45
2.5	Hydro Power	48
2.6	Micro-hydro Energy Resource (MHER)	53
2.6.1	Micro Hydro Plant (MHP)	54
2.7	Energy Controller System (ECS) on Hybrid Renewable Energy System	55
2.7.1	Hybrid Renewable Energy Control Methods	56
2.7.2	Programmable Logic Controller Modelling / Programming Method	57
2.7.3	Slave / Remote Terminal Unit (RTU)	58
2.7.4	Master Microcontroller	58
2.8	Hybrid Renewable Energy Controller Development	59
2.8.1	Hybrid Renewable Energy Control Optimization	60
2.9	Controllers Rudiments	60
2.9.1	Integrator Controller Analytical Model	61
2.9.2	Proportional Integral Analytical Model	62
2.9.3	Proportional Integral Derivative Analytical Model	63
2.9.4	Mathematical Model of Control	64

2.10	Hybrid Photovoltaic, Micro Hydro, PEMFC, Utility RE System	65
2.10.1	Hybrid Controller Signal Inputs	66
2.11	Energy Controller	67
2.12	Model Verification	67
2.13	Research Gap	68
2.14	Chapter Summary	69
	CHAPTER 3: METHODOLOGY	71
3.1	Introduction	71
3.1.1	Research Work Process (Flow Chart)	72
3.2	HRE Controller of Energy System Description	72
3.2.1	Controller Conventional Theoretical Model	76
3.2.2	State Space Model	77
3.2.3	Sequential Logic	78
3.2.4	Feedback Control	78
3.2.5	Supervisory Control and Data Acquisition (SCADA)/Remote Terminal Unit	79
3.2.6	Practical Block Diagram of MH, SPV, EMS and Utility Design Model	80
3.2.7	Optimal HRE Controller System Design Features	81
3.2.8	Optimal Controller Option	81
3.3	Embedded Sequential Logic Controller	82
3.3.1	Simulation-based Design	83
3.3.2	Methodology	85
3.4	Feasibility Data Acquisition	86
3.5	Design Model	91
3.5.1	Design Process Flow Chart	91

3.6	Hybrid RE Controller Model	93
3.7	Limitations of the Study	97
3.8	Requirements Definition	98
3.9	Energy Controller System Specification	98
3.10	Simulation-Based Design Model	99
3.11	Algorithm Design	100
3.12	Conceptual Framework	102
3.13	Software	104
3.14	Simscape Hybrid MH / SPV / PEMFC / Utility Simulation-based Design	107
3.15	MH Simscape Power System Model	111
3.16	PEMFC Simscape Power System	115
3.17	Utility Simscape Power System	116
3.18	Hybrid MH, SPV, PEMFC, Utility grid Sequential Multiport-Switch	117
3.19	Single Source Verification of FSM Model	117
3.20	Chapter Summary	121
	CHAPTER 4: RESULTS AND DISCUSSION	123
4.1	Introduction	123
4.2	Results and Discussion of Simulation-Based Designed HRE Controller	124
4.2.1	HRER Sinusoidal Inputs / Controller Trajectory Response	126
4.3	Standalone Power System Load Profile	128
4.3.1	MH Simscape Power System Model Simulation	129
4.3.2	SPV Simscape Parallel and Series RLC load Profile	136
4.3.3	SPV Poly-Phase Parallel RLC load curves	136
4.3.4	SPV Poly-Phase Series RC Load Curves	141

4.3.5	Proton Exchange Membrane Fuel Cell	145
4.3.6	Utility Grid Simscape Model response	149
4.3.7	Discrete (Digital Logic) Contour	152
4.3.8	Mathematical Simulation Iterate Model (FSM)	154
4.3.9	Construction of Improved HRE Controller	155
4.4	Simulation and Analysis	157
4.4.1	Discrete Structure Data Results	159
4.4.2	Design Pseudo Code script	160
4.4.3	Sequential Control Flow Chart	161
4.4.4	Digital Logic Table	162
4.5	HRE Controller Trajectory Verification / Characteristics	167
4.5.1	Side-by-Side Verification of Standalone FSM Model	168
4.5.2	HRE Model Verification	170
4.6	Chapter Summary	170
	CHAPTER 5: CONCLUSION AND RECOMMENDATIONS	172
5.1	Introduction	172
5.2	Conclusion	172
5.3	Design Contribution	173
5.4	Limitations and Further Work	175
5.5	Recommendations	176
	REFERENCES	177
	APPENDICES	198

LIST OF TABLES

		Page
Table 2.1	Hybrid Renewable Energy Models	28
Table 2.2	SPV Socioeconomic / Physical / Technological Features (Akinyele et al., 2015)	38
Table 2.3	Lead Acid and PEMFC Energy Storage System Features (Islam et al., 2012)	44
Table 2.4	Hydro Category and Power Capacity (Loots et al., 2015)	52
Table 2.5	Common Hydro Turbine Types and application sites (Kelly et al., 2013)	52
Table 3.1	Meteorological Data of Sri Aman Station/Semulong Ulu (Bandy & Zainal- Abidin, 2018; Basak et al., 2012) and Appendix G solar site data	89
Table 3.2	Sarawak Energy Berhad (SEB) Steady-State Sinusoidal Voltage Level at Normal Conditions (SEB, n.d.)	90
Table 4.1	HRE Control Input Summary (threshold control) of the input data passed to the output	127
Table 4.2	HRE Controller Energy Sustainability Index	155
Table 4.3	Interpretation of HRE Controller Logic Function Pseudo Code and Flow Chart	163
Table 4.4	Summary of Digital Logic Embedded Sixteen-Bit Microprocessor	164

LIST OF FIGURES

		Page
Figure 2.1	Energy HRE Distribution Block Diagram	18
Figure 2.2	Complete Solar Photovoltaic Power System (Taghvaei et al., 2013)	31
Figure 2.3	Solar irradiance distribution curve (Tyagi et al., 2012)	33
Figure 2.4	Equivalent circuit of SPV (Alsadi & Alsayid, 2012)	33
Figure 2.5	I-V and P-V characteristics (La Manna et al., 2014)	34
Figure 2.6	Total Cross-Tie (TCT) of PV array for sizing SPV (Shah & Patel, 2017)	39
Figure 2.7	SPV DC-AC inverter / converter with MPPT block diagram (Mohan & Kurub, 2012)	41
Figure 2.8	Cascaded (multiple inputs) H-bridge multilevel inverter (Mohan & Kurub, 2012)	42
Figure 2.9	Typical cascade (multiple inputs) H-Bridge inverter output to be input to HRE controller (Mohan & Kurub, 2012)	42
Figure 2.10	General Component of MH Plant (Ardizzon et al., 2014)	49
Figure 2.11	A Typical Run-of-River Hydropower (Nasr, 2014)	49
Figure 2.12	MH Turbine Classifications (Okot, 2013)	51
Figure 2.13	Hydraulic Cross-Flow Turbine (Okot, 2013)	51
Figure 2.14	Component View of MH Power Plant (Kumar & Katoch, 2014)	54
Figure 2.15	Block Diagram of Programmable Logic Controller (micro controller)	58
Figure 2.16	An Integrator Block Diagram, box (Isidori, 2017)	61
Figure 2.17	Block Diagram of Linear 'PI' Controller Plant (Lo & Ansari, 2012).	63

Figure 2.18	PID Block Diagram Controller without Plant (Chakraborty, 2016)	64
Figure 2.19	HRE and Energy Management System Diagram	66
Figure 3.1	Research Work Process (Flow Chart)	73
Figure 3.2	Block Diagram of Hybrid MH, SPV, ESS and Utility grid RE control	79
Figure 3.3	Cables/Wireless interface of Hybrid Multiport / HRE Controller Block Diagram	80
Figure 3.4	Controller Structure	84
Figure 3.5	Malaysia Map Average Solar Radiation (13.33 to 21 MJ/m ² /day), (Mekhilef et al., 2012)	87
Figure 3.6	Sample of Days, Solar Radiation, and Temperature Excel Records from July 2013-Dec. 2015 (Bandy & Zainal Abidin, 2018)	87
Figure 3.7	Design Process Flow Chart/Algorithm	92
Figure 3.8	HRE controller Flow Chart for MH, SPV, ESS and utility system	100
Figure 3.9	HRE System Process, Iterative Algorithm Simulation-Based Design	101
Figure 3.10	Three-Design Options Flow Chart	103
Figure 3.11	HRE Plant and Controller Block	104
Figure 3.12	FMS Hybrid Model Plant and Controller	105
Figure 3.13	Plant Block Diagram	106
Figure 3.14	HRE Controller events State Diagram	107
Figure 3.15	Simscape Hybrid MH, SPV, PEMFC and Utility grid / FSM Controller	109
Figure 3.16	Sims-cape Hybrid MH, SPV, PEMFC and Utility grid / Multiport-Switch	110

Figure 3.17	Simscape MH Power System and Electric Circuit	111
Figure 3.18	Simscape SPV Ten-Panel Power System and Electric Circuit	112
Figure 3.19	Simscape SPV Array Power System and Electric Circuit	113
Figure 3.20	Simscape SPV Power System / Electric Circuit	113
Figure 3.21	Simscape SPV Ideal Model Ten-Panel	114
Figure 3.22	Harmonic LC Filter	114
Figure 3.23	Simscape PEMFC / Electric circuit / Series RLC Load	115
Figure 3.24	Simscape PEMFC Block Sub-system / Electric Circuit / Series RLC Load	115
Figure 3.25	Simscape PEMFC Recharge with MH Resource Model	116
Figure 3.26	Simscape Utility grid Power / Electric Circuit / Parallel RLC Load	116
Figure 3.27	MH Input FSM Model	120
Figure 3.28	FSM Model of Single RE Input	120
Figure 4.1	MH Volumetric Flow Rate	129
Figure 4.2	MH Mechanical Rotational Angular Displacement	130
Figure 4.3	MH Mechanical Rotational Velocity	130
Figure 4.4	MH Turbine Mechanical Torque / Load Current	131
Figure 4.5	Mechanical Power / Load Current	132
Figure 4.6	MH Poly-Phase Load Sinusoidal Voltage	132
Figure 4.7	Mechanical Revolution / Load Voltage / Current	133
Figure 4.8	MH Poly-Phase Sinusoidal Load Current	133
Figure 4.9	Simscape MH Parallel RLC load Voltage / Current	134
Figure 4.10	MH Poly-Phase Load Active Power	135
Figure 4.11	MH Poly-Phase Load Reactive Power	135

Figure 4.12	Pulse Width Modulation Generator	136
Figure 4.13	SPV Simscape Parallel RLC Load Voltage	137
Figure 4.14	Simscape SPV Filtered Parallel RLC Load Voltage	138
Figure 4.15	Simscape SPV Parallel RLC Load Current	138
Figure 4.16	Simscape SPV Filtered Parallel RLC Load Current	139
Figure 4.17	SPV Simscape Parallel RLC Load Active / Reactive Power	140
Figure 4.18	SPV Simscape LC Filter Parallel RLC Load Voltage / Current	140
Figure 4.19	Solar Irradiance	141
Figure 4.20	Simscape SPV Poly-Phase Series RC Load Voltage	142
Figure 4.21	Simscape SPV with Filter Poly-Phase Series RC Load Voltage	142
Figure 4.22	Simscape SPV Poly-Phase Series RC Harmonic Load Current	143
Figure 4.23	Simscape SPV with Filter and Series RC Load Current	143
Figure 4.24	Simscape SPV Power RC Series Load Active Power Curve	144
Figure 4.25	Multimeter Simulated Series RC Load Voltage / Current Curves	144
Figure 4.26	PEMFC Hydrogen Efficiency Assessment	145
Figure 4.27	PEMFC DC-DC Boost Converter Output Voltage	146
Figure 4.28	Sinusoidal PEMFC Parallel RLC Load Voltage	146
Figure 4.29	PEMFC Simscape Power Model combined Load Current / Voltage	147
Figure 4.30	PEMFC Simscape Power Model with Filtered Load Current / Voltage	147
Figure 4.31	PEMFC for Parallel RLC Load Active Power	148
Figure 4.32	Simulation of PEMFC Simscape Reactive Power	149
Figure 4.33	Utility Model Poly-Phase Parallel RLC Load Voltage Response	150
Figure 4.34	Utility Model Poly-Phase Parallel RLC Load Current	150

Figure 4.35	Utility Model Poly-Phase Parallel RLC Load Active Power	151
Figure 4.36	Utility Model of Poly-Phase RLC Parallel Load Reactive Power	151
Figure 4.37	Unit Step Trajectory of HRE Controller	152
Figure 4.38	Response of Single RER as Logic Zero Energy	153
Figure 4.39	FSM HRE Controller ESI from Table 4.1	156
Figure 4.40	FSM HRE Controller Trajectory / ESI / Duty Cycle	158
Figure 4.41	HRE Controller Zero EI / Duty Cycle for One Sinusoidal Signal	159
Figure 4.42	Digital Logic (Discrete) Sequential Control Flow Chart	161
Figure 4.43	HRE Controller Trajectory Verification / Characteristics	167
Figure 4.44	Single Input FSM Model Trajectory / Duty Circle / EI Verification	168
Figure 4.45	Standalone Single Source Controller Transfer Function	169

LIST OF ABBREVIATIONS

AC	Alternating Current
BESS	Battery Storage System
CAES	Compressed Air Energy Storage
CdTe	Cadmium Telluride
CECS	Central Energy Controller System
CIGS	Copper-Indium-Gallium-Dieseline
ESS	Energy Storage System
EUI	Energy Unsustainability Index
EV	Electric Vehicle
FSM	Finite State Machines
GA	Generic Algorithm
GaAs	Gallium Arsenide
GHG	Green House Gas
GMPP	Global Maximum Power Point
GUI	Graphical User Interface
HDI	Human Development Index
HCI	Human Computer Interaction
HEC	Hybrid Energy Control
HECS	Hybrid Energy Control System
HES	Hybrid Energy System
HESS	Hybrid Energy Storage System
HMI	Human Machine Interface

MPPT	Maximum Power Point Tracking
ODE	Ordinary Differential Equation
PAC	Programmable Auto. Controller
PEMFC	Proton Exchange Membrane Fuel Cell
PH	Pump Hydro
PD	Proportional Derivative
PI	Proportional Integral
PID	Proportional Integral Derivative
PH	Pump Hydro
PHES	Pump Hydro Energy Storage
PHSS	Pumped Hydro Storage System
PLC	Programmable Logic Controller
P&O	Perturb & Observe
PSCAD	Power System Computer Aided Design
PSO	Particle Swam Optimization
PWM	Pulse Width Modulation
PV	Photovoltaic
RE	Renewable Energy
RER	Renewable Energy Resource
RLC	Resistive Inductive and Capacitive
RTD	Resistance Temperature Detector
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SCORE	Sarawak Corridor of Renewable Energy

SDG	Sustainable Development Goals
SDEG	Standalone Distributed Energy Generation
SEB	Sarawak Electricity Berhad
SFC	Sequential Function Chart
SISO	Single Input Single Output
SPV	Solar Photovoltaic
SREPP	Small Renewable Energy Power Program
SSS	Standalone Single Source
TC	Thermocouple
TCT	Total Cross-Tie
TNB	Tenaga Nasional Bernhard
TOC	Theory of Constraint
UI	User Interface
UNIMAS	Universiti Malaysia Sarawak

CHAPTER 1

INTRODUCTION

1.1 Introduction

Different countries have diverse energy challenges like remote rural distance; erratic energy addressed using Standalone Distributed Energy Generation (SDEG) from Dispersing Renewable Resources (DRR). A strategic approach tailored by individual countries depend on regional situations to meet the energy irregularity and shortage. Various nations or situations have different energy demands that present varied energy encounters, and related solutions. Diverse and disperse remote rural populations of the world mostly rely on standalone single source lack sustainable and adequate electricity supply. SDEG is a priority requirement for the socioeconomic and entrepreneurial development of remote rural communities like in Malaysia. Remote settlers use various fossil fuels for daily energy requirements despite the trend of increasing fuel costs, and carbon emission health hazards due to environmental impacts (Alam et al., 2013; Kaygusuz, 2012).

Standalone power supply with a single source is the common electrical structure in rural remote locations so the loss of energy probability becomes a common phenomenon. Commercial and industrial activities anywhere require sustainable energy therefore alternative power systems such as Hybrid Renewable Energy Resources (HRER) and its components have energy sustainability impacts (Alam et al., 2013). HRER components like the electric energy resources, Proton Exchange Membrane Fuel Cell (PEMFC) and energy automation hybrid controller or hybrid switch eventually increase power consistency at less cost (optimized).

Solar Photovoltaic (SPV) is one of the Renewable Energy (RE) sources that are truly intermittent, and not stockpiled like the conventional fossil system. Integrating Micro Hydro (MH) with complementary SPV, energy storage and other energy components as a hybrid could improve energy sustainability. The daily maximum energy demand usually lasts for several hours of every day. Whereas, solar energy is intermittent and the backup or storage service lasts for shorter duration or the MH flow rate is periodically dynamic. HRER power supply sequential transition (Borges, 2012) can extend supply sustainability, all the same, the standalone hydro last as long as run-of-the-river water flow, it is said to be intermittent.

The simulation -based design of Hybrid Renewable Energy System (HRES) use multiport-switch logic patterns of crossbreed energy sources. The SPV and MH primary meteorological data, energy storage and utility grid become the inputs to the hybrid controller or multiport-switch as output. The hybrid solar photovoltaic and micro-hydro supply disperse communities using hybrid standalone infrastructure. Residential, industrial and commercial consumers of electricity supplied with energy for socioeconomic activities require optimal cost and supply standby (Amer et al., 2013).

The electricity delivery becomes sustainable when the subsystems have alternative backups in the form of hybrid structure. Development of HRER for power sustainability involves sites, resource data feasibility analysis to determine Renewable Energy System (RES) availability level. The design, modelling, and simulation of subsystems like hybrid energy resources, Hybrid Energy Storage Systems (HESS) or Hybrid Renewable Controller (HRC) become important (Amer et al., 2013). The proposition of hybrid energy control for hybrid MH, SPV with PEMFC as ESS, and utility grid or other RE using HRC controller or hybrid switch platform enhance energy sustainability. The plan of simulation-based design