Modeling and Simulation of Fuzzy logic based Hybrid power for Irrigation System in case of Wonji-Shoa Villages

Adisu Teshale, Adama Science and Technology University (2012)

ABSTRACT

Energy is the fuel for growth of a country. An increased access to electricity enhances opportunities for industrial development and improves health and education. Renewable energies (RE) have a large potential to maintain sustainable energy.

Hybrid renewable energy systems, is a system that combines more than one renewable energy technology. The hybrid of photovoltaic and wind turbine is one of the most promising applications of renewable energy technologies in remote areas. Ethiopia is one of the developing countries in which most parts of the country are living in rural areas. Wonji-Shoa villages are villages found in south east of the capital Addis Ababa.

In this thesis a wind/solar/diesel hybrid power for irrigation system is modeled and simulated on MATLAB software. Moreover; a fuzzy logic control system has been designed and modeled on MATLAB. From the simulation result, it has been observed that simulation for different cases when the days are sunny, windy and rainy it has been found to be effective to supply the intended power demand (for pumping).

Keywords: *hybrid power system; Water pumping; MATLAB; Fuzzy logic control*

1. INTRODUCTION

The World Energy Council proposed a target of a minimum of 500 kWh per person per year for everyone in the world by 2020. To achieve a modest target, African countries need to undertake strenuous efforts. In many of African countries electricity is a commodity given only for cities. Most of the rural area has no access of electricity. They use wooden biomass for their energy need. But now a day due to a rapid growth of population and global warming, the rural people are suffering from absence of enough wood and food.

Distributed generation seems to be the only viable option to increase the level of electrification in any significant manner. Renewable energies (RE) have a large potential to maintain sustainable energy. Increasing access of electricity in rural area via renewable energy will encourage poverty reduction in the country. The most common Renewable Energy Sources are: Solar, Wind, Hydropower, Geothermal and Bio energy.

Large parts of the countryside receive sufficient solar radiation throughout the year. The average wind velocity in many regions is known to be large enough for electric power generation. The mini/micro hydropower resource base in countries like Ethiopia and Uganda is probably one of the largest in Africa.

A hybrid power system is technology of integrating renewable energy sources. Mostly it integrates energy sources with fossil fuel generators (Diesel/petrol) to provide reliable electrical power. They are generally independent of large centralized electric grids and are used in remote areas. On a cloudy windy day when the solar panels are producing low levels of electricity, the wind generator compensates by producing a lot of electricity.

There are generally two accepted hybrid power system configurations [39]:

• Systems based mainly on diesel generators - renewable energy is used for reducing fuel consumption;

• Systems relying on the renewable energy source - with a diesel generator used as a backup.

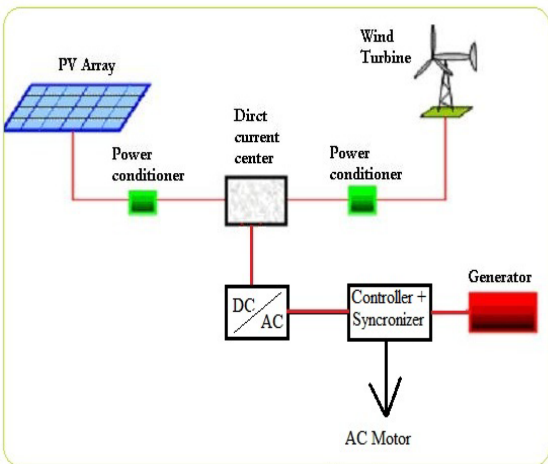

Figure 1.1 Block diagram of intelligent controlled hybrid power system

1.2 Statement of the Problem

Ethiopia, in addition to the persistent drought and famine, is suffering from scarcity of energy. It is known that the development of any country depends on the amount of energy consumed. Energy consumption is proportional to the level of economic development. The per capital energy consumption in Ethiopia is very low. This had a direct impact on development of the country.

This all problems are not due to the absence of resource, but it is due to the lack of resource utilization. The country has surplus resource of water and renewable energy resources. Ground water and sunlight are highly available, which make renewable energy powered water pumping more effective.

As more than 75% of the people in Ethiopia are living in rural area, agriculture is the day to day activity. Farming is the main economic source of the people living in rural area of Ethiopia. But due to the lack of water pumping, they are forced to farm once a year during the summer season only. As a result farmers face challenge to provide enough grain for the population of the country. The main thing which makes the problem more challenging is the increasing of demand for food and decreasing of productivity. Very few peoples of the country are using diesel powered water pumps. Now a day the price of diesel water pump has been increased rapidly. Figure 1.2 indicates the exponential increase of diesel water pump price in Ethiopia.

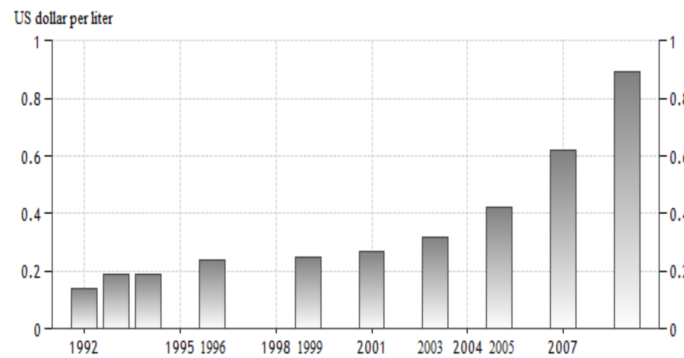

Figure 1.2 Diesel water pump price in Ethiopia from 1992 – 2008 [Source: Tradingeconomics.com, on July 2008]

In addition to increment in capital cost the fuel price has been increased throughout the country as well as in the world.

Using a single renewable energy source is not reliable as it depends on season of the year. For example: one big problem of PV system is it can't supply power during adverse weather and night. Over sizing the PV array and enlarging the battery storage may improve reliability of PV system. Since PV array and battery are the two most costly system components, it needs high capital cost. Hybridizing PV system with other renewable energy sources often reduces the need for over sizing the PV array.

During design of hybrid system it is needed to design efficient control system. If the control system failed to switch to an appropriate power source at desired time, the efficiency of the system will decrease. Hence attentions should be given to the control system during designing of hybrid power system.

1.3 Objective of the Study

This thesis work comprises of the following general and specific objectives:

General objectives

The general objective of this study is to design, model and simulate a fuzzy logic controlled solar/wind/diesel hybrid power for irrigation system for Wonji-Shoa villages.

Specific Objective

The specific objectives of this thesis are:

- ✓ To assess the potential of solar and wind energy sources around Wonji-Shoa area.
- ✓ To model and simulate solar/wind/diesel hybrid power system on MATLAB software.
- ✓ To design and model a fuzzy logic control system
- ✓ To estimate Life cycle cost of the system

1.4 Significances of the study

The Government of Ethiopia is undertaking a number of encouraging steps to meet and exceed the Millennium Development Goals related to water supply. These include the development and adaptation of Universal Access Program aimed to attain rural water supply. According to [1], it was aimed to increase water access level of Ethiopian rural area to about 98% by 2012. To achieve this government has been prepared the new five year transformation and development plan since, 2010. According to the plan, the country will be transformed from less income to medium income country within two decades. The agricultural sector is expected to satisfy the food demand throughout the country. To make this possible, the traditional and backward agricultural practice should be replaced by modern irrigation system.

This thesis will be an important component to achieve the goals of the Universal Access Program for water supply and sanitation services. Hybrid pumping systems is more reliable; consume less fuel and Low maintenance than diesel system alone. It also helps to minimize air pollution.

Generally, designing such kind of environmental friendly power system for irrigation will highly helpful for:

1. ***Rural communities***: The primary beneficiaries of this project are people in the rural communities who would be the direct users of the water scheme.
2. ***Governmen***t - various federal and regional stakeholders in water sectors to meet Millennium Development Goals related to water and five year transformation and development plan.
3. ***Private sector enterprises:*** they will be benefit from the supply of solar and wind pumping equipment, spare parts and repair services and get job opportunity.
4. ***Researchers*** who carry out related to HPS. The thesis can be used as reference for any further work on intelligent controlled hybrid power system.

2. Estimation of Water Requirement in the Case Study

This thesis is intended to design a fuzzy logic controlled hybrid power for irrigation system in case of Wonji-Shoa sugar factory. In designing the system the first step is to determine the load demand (water requirement) on a land of 100 hectors (1000m x 1000m = 1000000m^2). From the crops growth period, the growth period of common crops are: maize needs 80-110 days to grow, Onion needs 70-95 days to grow, and Sorghum needs 120-130 days to grow and the like. From this one can cultivate three times within a year i.e. season-1(from May to August), Season-2 (September to December), Season-3(January to April).

ISBN: 978-1-61804-291-0

Using Blaney-Criddle formula, the reference crop evapotranspiration (ET_o) in mm per unit time is calculated as: $ET_o = p\ (0.46T_{mean} + 8)$.

Where, p = mean daily percentage of annual daytime hours and T_{mean} = mean temperature.

Considering crop to be grown is Maize, the total growing season is 110 days (sum of all 4 crop stages according to Table 3.8). Hence, ET_o of the crop has been obtained 4.8 mm/day over the total growing season. The Crop water Requirement can be obtained by multiplying k_c and ET_o of the crop. Therefore the crop water requirement has been found approx. 607.5 mm per total growing season.

Again considering the Crop to be grown is Sorghum, using the same procedure the total water requirement per season has been found 633.6 mm.

One mm per day means the plant needs water up to 1mm depth of the root of plant. From the above obtained data, the volume of water required can be calculated as:

Volume of water required [m^3] = water depth [m per season] * Area of land to be irrigated [m^2] = 0.6336m/season *100,000,000m^2

= 63,360,000 m^3 per season

NB – one season means 120 days

From 100% water supplied 50% of water will be used by crops and 50% of water will be lost due to Delivery losses (15%), Application losses (35%). Therefore the grand total water requirement will be 2x 63,360,000 m^3 = 1,267,200 m^3 per season or 10560 m^3 per day. Hence the discharge per day (Q) = 10560m^3/day or 0.122 m^3 /s.

Since 1m^3 = 1000 liter, 0.122m^3/s =122 liter /s.

3. MATLAB Modeling of PV System

MATLAB software is one of the most widely used engineering software. It models, simulates, and analyzes dynamic systems. It enables to pose a question about a system, model the system, and see what happens. With Simulink, one can easily build models from scratch, or modify existing models to meet its needs [34]. PV system, wind turbine and diesel generators are modeled independently On MATLAB/SIMULINK.

A general block diagram of the PVA model for GUI environment of Simulink is given in Fig. 3.1. The overall program has been written on M-file.

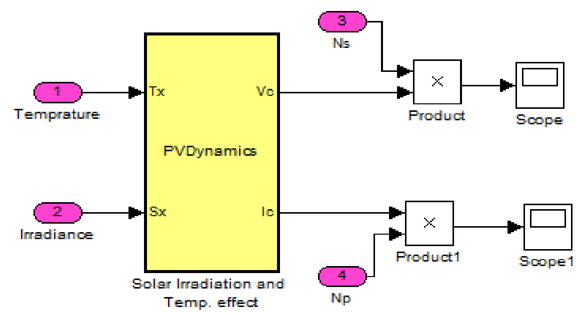

Figure 3.1 Solar PV MATLAB/SIMULINK model

The universal bridge rectifier is subjected to convert the incoming 240 DC voltage to AC voltage. The transformer is used to step up the generated AC voltage. The pulse signal was generated using pulse generator and used as an input for inverter circuit.

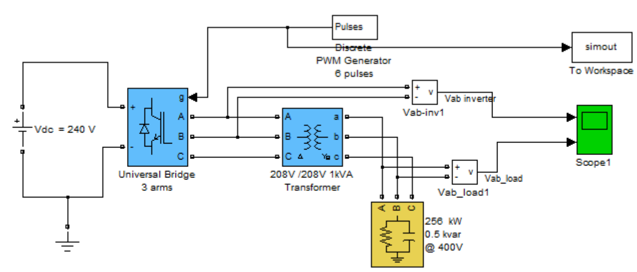

Figure 3.2 PWM Inverter MATLAB/SIMULINK model

SimPower library is a library which consists of power system equipments. Wind turbine is also found in this library. In the following MATLAB model, first wind turbine was modeled having three inputs: generator speed in per unit, pitch angle and wind speed. Gain in this model represents the gears used. The output of the turbine is mechanical torque. This torque is subjected to drive the generator.

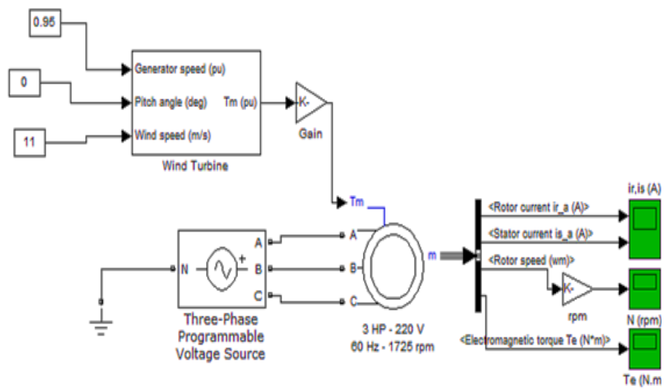

Figure 3.3 SIMULINK models of wind turbine and generator

A diesel generator is the combination of a diesel generator with an electrical generator often called an alternator to generate electrical energy. A synchronous generator is modeled on MATLAB/SIMULINK.

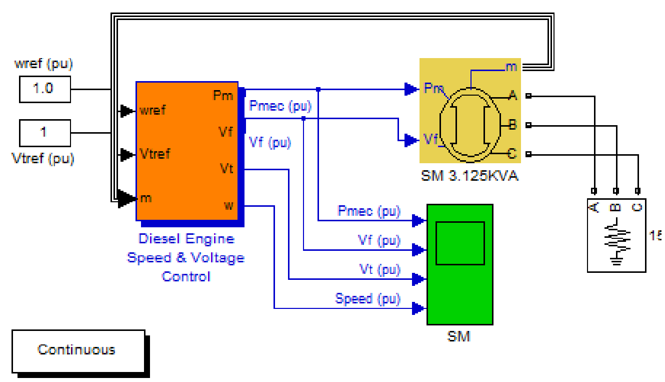

Figure 3.4 Simulink model of an emergency diesel generator

There are two types of fuzzy inference systems that can be implemented on MATLAB Fuzzy Logic Toolbox: Mamdani type and Sugeno-type. These two types of inference systems vary somewhat in the way outputs are determined. In Matlab fuzzy logic toolbox, there are five parts of the fuzzy inference process.

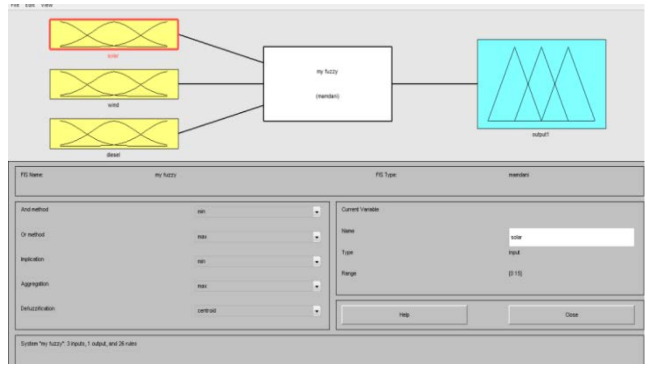

Figure 3.5 Fuzzy model

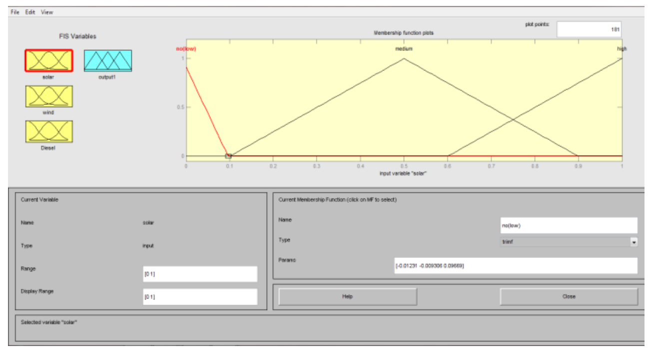

Figure 3.6 Fuzzy logic membership function for wind input

Here is the model of fuzzy logic control having three inputs and one output. In the control box, a set of rules have been written. The system will operate in accordance to the rules set. The following figure 4.35 shows the fuzzy logic rules and operation of the system in different operating conditions.

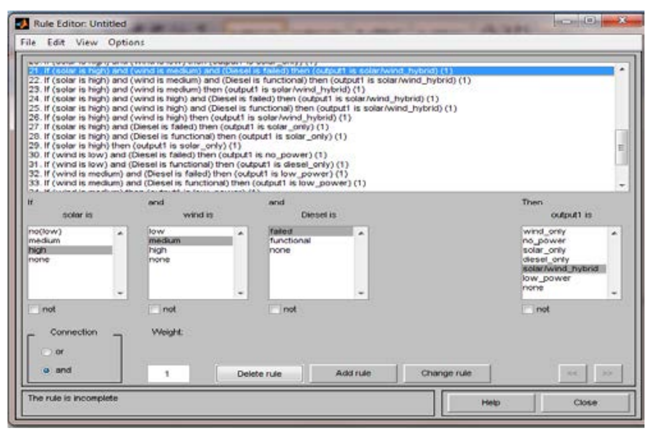

Figure 3.7 Fuzzy logic rules

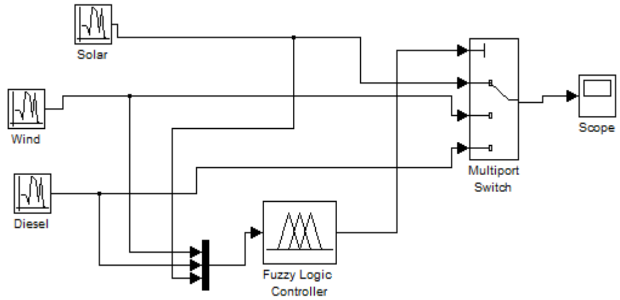

Figure 3.8 Fuzzy logic Control (switching) System

4. SIMULATION RESULT

Before connecting together (Hybridizing) all components (system) each components and systems are modeled and simulated alone.

4.1 MATLAB Simulation Result of PV Output Voltage

After modeling the above model on MATLAB/SIMULINK the following result has been obtained.

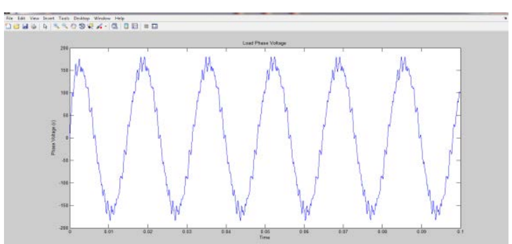

Figure 4.1 PV output current

4.2 Simulation Result of Wind Generator

After modeling the turbine on MATLAB/SIMULINK, the rotor output current wave form and stator current wave form are given in figure below.

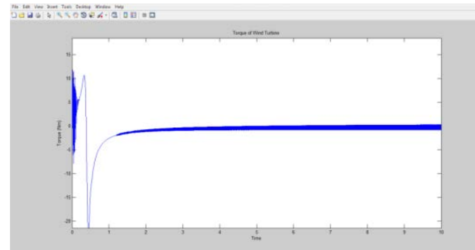

Figure 4.2 simulation result of wind turbine torque

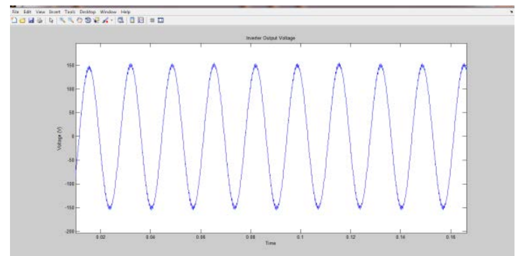

Figure 4.3 output current of wind turbine

4.3 Simulation Result of Standby Diesel Generator

The following three phase output signal shown in figure 4.4 was obtained from emergency diesel generator modeling.

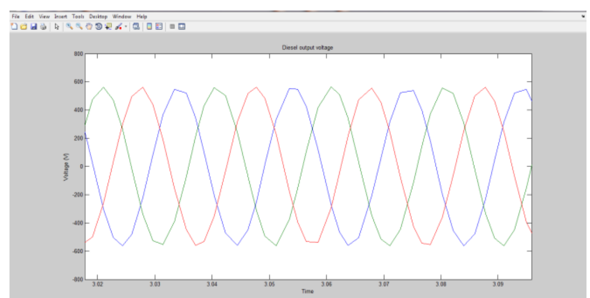

Figure 4.4 Simulation Result of voltage of Emergency Diesel Generator

4.4 Matlab Simulation Result of Fuzzy Logic Control

The fuzzy logic switch is used to switch the load to the available power sources in accordance to written fuzzy rules.

During cloudy and windy time, since the available energy source is wind energy the fuzzy rule will switch to wind turbine intelligently (automatically). Likewise during

ISBN: 978-1-61804-291-0

sunny day the switch will switch to solar energy. If more than two energy sources are available at a time it will hybridize them. The following figure shows the simulation result of a fuzzy logic switch during different conditions.

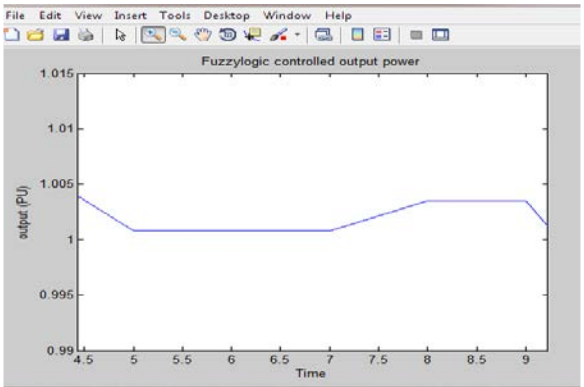

Figure 4.5 Fuzzy logic output in pu.

5. CONCLUSION

In this thesis a fuzzy logic based (controlled) hybrid solar/wind energy powered irrigation system has been modeled on MATLAB/SIMULINK. As the aim of the thesis is to develop a minimized environmental impact irrigation system to decrease the dependency of food production on traditional energy sources, first a renewable energy source assessment has been made. In this thesis sprinkler irrigation is used as it is efficient type of irrigation. Hence the total power demand to irrigate 100 hectors is found to be 256 KW. Fuzzy logic control is used to select the appropriate power source for water pump depending on the resource available. According to the rules written on fuzzy logic control system the possible power sources can be solar energy alone, wind power alone, hybrid of solar and wind energy or diesel generator. Since, fuzzy logic system will consider all the possible cases, no need to simulate separate cases.

Generally, from the simulation result, it has been observed that fuzzy logic controlled hybrid power for irrigation system can effectively supply the intended power demand in different cases. These cases are during calm and sunny day, during wind day, during sunny and windy day and during rainy days.

6. REFERENCES

[1] "*Utilization of Solar and Wind Energy for Rural Water Supply in Ethiopia*" African Water Facility, Appraisal Report, Bp 323 – 1002 Tunis Belvédère (Tunisia), December 2008

[2] Kala Meah et al. 2006 "*Solar photovoltaic water pumping—opportunities and challenges*" Renewable and Sustainable Energy Reviews volume 12 (2008) 1162–1175

[3] Zvonimir Glasnovic and Jure Margeta et al. (2006), "*A model for optimal sizing of photovoltaic Irrigation water pumping systems*" Solar Energy volume 81 (2007) 904–916

[4] A. Hamidat et al. (2002) "*Small-scale irrigation with photovoltaic water pumping system in Sahara regions*" Renewable Energy 28 (2003) 1081–1096

[5] A.Hadj Araba F Chenlob K Mukadamb Balenzateguib, 1999 "*Performance of PV water Pumping systems*" Renewable Energy volume 18 (1999) 191 – 204 www.elsevier.com

[6] Ahmed M. Al-Zoheiry, M.S. (2006) "*Modeling a Drip Irrigation System Powered By Renewable Energy Source*" The Ohio State University 2006

[7] P. Jayakumar, 2009, "*Solar Energy Resource Assessment Handbook*" Asian and Pacific Centre for Transfer of Technology of the United Nations – Economic and Social Commission for Asia and the Pacific (ESCAP), 2009.

[8] Mezigebu Getinet 2011, "*design and simulation of a more reliable photovoltaic based traffic light system*" Adama University [UN Published]

[9] Kalogirou, Soteris. "*Solar energy engineering: processes and systems*" Academic Press is an imprint of Elsevier, 84, Theobald's Road, London WC1X 8RR, UK, 2009 [BOOK]

[10] Anca D. Hansen "*Models for a stand-alone PV system*" Danka Services International A/S, 2001 [unpublished]

[11] Sharew Anteneh Mekonnen, "*Solar Energy Assessment in Ethiopia Modeling and Measurement*" Addis Ababa University, Ethiopia, 2007 [unpublished]

[12] A. Mellit "*Sizing of photovoltaic systems: a review*" Renewable Energy Vol. 10 N°4 (2007) 463 – 472

[13] Sheeraz Kirmani et. al "*Techno Economic Feasibility Analysis of a Stand-Alone PV System to Electrify a Rural Area Household in India*" International Journal of Engineering Science and Technology Vol. 2(10), 2010, 5231-5237.

[14] Mahmoud Salah Ismail Abdel-Qader, "*Simulation of a Hybrid Power System Consisting of Wind Turbine, PV, Storage Battery and Diesel Generator with Compensation Network: Design, Optimization and Economical Evaluation*" An-Najah National University Faculty of Graduate Studies, 2008

[15] Tomas Petru "*Modeling Of Wind Turbines for Power System Studies*" Chalmers University of Technology Gäoteborg, Sweden 2001

[16] Lucian MIHET-POPA andVoicu GROZA "*Modeling and Simulation of a 12 MW Wind Farm*" Advances in Electrical and Computer Engineering Volume 10, Number 2, 2010

[17] J. Soens et al. "*Wind Turbine Modeling Approaches for Dynamic Power System Simulations*"

[18] Gabriele Seeling-Hochmuth "*Optimisation of Hybrid Energy Systems Sizing and Operation Control*" Kassel University Press Gmbh 1999

[19] Arnusorn Saengprajak "*Efficiency of Demand Side Management Measures in Small Village Electrification Systems*" Kassel University press GmbH, Kassel, 2007 www.upress.uni- kassel.de

[20] Bimrew Tamrat "*Comparative Analysis of Feasibility of Solar PV, Wind and Micro Hydro Power Generation for Rural Electrification in the Selected Sites of Ethiopia*" Addis Ababa University of Mechanical Engineering, 2007[unpublished]

[21] N. Phuangpornpitak and S. Kumar, 2007 "*PV hybrid systems for rural electrification in Thailand*" Renewable & Sustainable Energy Reviews 11 (2007) 1530-1543.

[22] Getachew Bekele "*Study In to the Potential and Feasibility of A Standalone Solar/wind Hybrid Electric Energy Supply System for Application in Ethiopia*" Department Of Energy Technology Royal Institute Of Technology, KTH Stockholm, December 2009

[23] Leake E. Weldemariam "*Genset-Solar-Wind Hybrid Power System of Off-Grid Power Station for Rural Applications Sustainable Off-Grid Power Station for Rural Applications*" Delft University of technology Delft, The Netherlands, 2010 [unpublished]

[24] Headley Stewart Jacobus "*Solar-Diesel Hybrid Power System Optimization and Experimental Validation*" University of Maryland, College Park, 2010

[25] Kevin M. Passino and Stephen Yurkovich "*Fuzzy Control*" Department of Electrical Engineering the Ohio State University, Addison Wesley Longman, Inc, 1998

[26] Jhon A. Duffie and William A.Beckman, "*Solar_Engineering_of_Thermal_Processes book*" 3rd edition, Solar Energy Laboratory, University of Wisconsin-Medison John Wiley & sons INC, 1997