Design and Simulation of Electrification By Solar-Wind Hybrid System

Aye Ei Ei Cho, Su Su Myat Mon
Department of Electrical Power Engineering,
Technological University, Thanlyin, Myanmar

ABSTRACT

With the rising energy demand and lack of infrastructure because of geographical condition of Pyin Kha Yaing Village, the whole village is still not inter-connected to National Grid System. This village is located in Ngapudaw Township, Ayarwaddy Division. The latitude and longitude of study case is 15.980992 and 94.400207 respectively. Presently, the electrification of Pyin Kha Yaing Village is carried out by steam boiler driven generator with burning of Rice-Husk. With this source, total average consumption is observed as 3.4 MWh/D. Instead of steam boiler generator driven, Solar-Wind Hybrid Generation system is employed for this place. A simulation model for wind-solar hybrid system is developed using the Matlab/Simulation software. The proposed model is combination of Wind Energy System, Photovoltaic (PV) array, Converter, Battery storage and inverter. The simulation model of solar-wind hybrid system for selected region is presented.

Keywords: *3Φ AC load; Battery bank; Converter; Matlab/Simulation; PV Generator; Wind Turbine*

1. INTRODUCTION:

The interest in renewable energy has been increased over last few years, especially after global awareness regarding the hazardous effect of fossil fuel burning.[1].Energy is the source of growth and the mover for economic and social development of a nation and its people. Renewable energy is derived from natural processes that are replenished constantly [2].

A photovoltaic material is a device which can capable of converting the energy contained in photons of light in to electrical current. The photovoltaic use semiconductor material for conversion of sunlight into electricity .PV cells do not use the suns heat to produce electricity rather they produce electricity directly when sunlight interacts with semiconductor materials in the PV cells [4].For increasing both voltage and current level, solar cell need to be connected both in series and parallel combination [6].Wind energy conversion system is used to capture the energy of wind to convert into electrical energy. Wind part consists of asynchronous generator and wind turbine. Asynchronous generator is basically user friendly and efficiency is good. Wind turbine requires to be kept in such a position so that it can get enough wind velocity and minimum density. In this thesis wind and solar energy makes a hybrid system. Hybrid system means more than one energy conversion system is included. The devices of this hybrid systems are PV array, boost converter, Maximum Power Point Tracker(MPPT)by using Perturb and Observe method, harmonic reducing filter, IGBT switch, three level bridge inverter, Voltage source converter(VSC),Asynchronous Generator ,wind turbine and power factor correction capacitor.

The photovoltaic array is a 1000kW subsystem. It is connected to three phase AC load through a DC-AC inverter where a P&O MPPT controller is applied. Furthermore, the wind turbine subsystem is a 330kW and it is equipped with a SEIG generator. The both systems of renewable energy are connected in parallel to power a common three phase AC load.

Here, the both systems of renewable energy (photovoltaic generator and the wind turbine system) are designed and simulated in section II and III. The designing and simulation of the hybrid power system

is carried out in section IV. Finally, the conclusion is given in the last section.

Figure (1) Location of the Pyin kha Yaing Village

I. DESIGNING AND SIMULATION OF THE PHOTOVOLTAIC GENERATORS

This section is devoted to simulate the PV generator using MATLAB/Simulink environment.

A. Designing of the photovoltaic generator
The characteristics of the photovoltaic model SunPower SPR-400E WHT-D are given in table I. The required daily average energy demand:

$$E_{rd}= E_d / (\eta_{bat} \eta_{inv} \eta_c)$$
$$E_{rd}=4859kWH/(0.95x0.90x0.98$$
$$=5799.02kWH$$

where,E_d = the daily average energy demand in watt hours
The average peak power:
$$P_{ave,peak} =E_{rd} / T_{sh}$$
$$P_{ave,peak} =5799.02kWH/6$$
$$=966.5kW$$

where , T_{sh}= the peak sun hours (hrs/day)
The total current of the system:
$$I_{dc} = P_{ave,peak} /V_{dc}$$
$$I_{dc}=966.5kW/600$$
$$=1.61kA$$

The number of modules in series:
$$N_{sm} = V_{dc}/ V_{rm}$$
$$N_{sm}=600/72.9=8 \text{ numbers}$$

The number of parallel modules strings:
$$N_{pm}= I_{dc}/I_{rm}$$
$$N_{pm}=1.61kA/5.49=293.26 \text{ numbers}$$
$$=293 \text{numbers}$$

The total number of modules:
$$N_{tm}= N_{sm} \times N_{pm}$$
$$N_{tm}=8x293=2344 \text{ numbers}$$

Where , V_{dc} =the dc voltage of the system
V_{rm} =the rated voltage of each module

TABLE I. CHARACTERISTICS OF THE PHOTOVOLTAIC ARRAY

Short circuit current (Isc)	5.87A
Open circuit voltage (Voc)	85.3V
Voltage at maximum power point Vpm (V)	72.9V
Maximum power	400.221W
Current at maximum power point Ipm(A)	5.49A
Solar Insolation	$1000W/m^2$
Filter Inductor	003µH
Nominal Solar Array voltage	680 V
Input Voltage	600V
DC link Capacitor	0.0138F

The photovoltaic array is coupled with the following parts:
-DC/AC inverter (controlled by a P&O MPPT technique)
-AC load (Three phase).
Furthermore, it has two input parameters: the solar irradiation and the ambient temperature.

II. SIMULATION OF THE WIND TURBINE SYSTEM

In another way, the wind turbine is considered as an important system of renewable energy [23].Generally, it is composed by:
-Wind turbine.
-SEIG generator
-6 Pulse Rectifiers

A. Designing of the wind turbine system
The characteristic of the Enercon E33 model wind turbine is used. The SEIG _WT system used for this simulation has the following characteristics: 330kW; 400V; 50 Hz and its parameters are given in Table II.

TABLE II. THE CHARACTERISTICS OF THE WIND TURBINE SYSTEM

Nominal phase to phase voltage $V_n(V_{rms})$	400V
Nominal frequency $f_n(H_z)$	50 H_z
LC Filter for 6 Pulse Rectifier(Filter Inductance)	61.43μF
LC filter for 6 pulse Rectifier(Filter Capacitor)	18.3mF
Wind Speed	10 m/s
Wind Energy	564.3kWh

III. DESIGNING OF THE BATTERY

The estimate energy storage:
$$E_{est} = E_d \times D_{aut}$$
$$= 5423.3 kWh \times 2 = 10846.6 kWh$$

The safe energy storage:
$$E_{safe} = E_{est}/D_{dish}$$
$$= 10846.6 kWH/0.8$$
$$= 13558.25 kWH$$

The total capacity of the battery bank in ampere-hours:
$$C_{tb} = E_{safe}/V_b$$
$$= 13558.25 kWH/2 = 6779125 Ah$$

The total number of battery:
$$N_{tb} = C_{tb}/C_b$$
$$= 6779125/1000$$
$$= 6779.125 \text{ numbers}$$

The no.of batteries in series:
$$N_{sb} = V_{dc} / V_b$$
$$= 760/2 = 380 \text{ numbers}$$

The no.of batteries in parallel:
$$N_{pb} = N_{tb} / N_{sb}$$
$$= 6780/380 = 17.8 = 18 \text{ numbers}$$

Where, D_{aut} = the number of autonomy days
D_{dish} = the maximum allowable depth of discharge

C_b = the capacity of the selected batteries in Ah

TABLE III. CHARACTERISTICS OF IGBT Pulse Width Modulation Inverter

Filter Capacitor	944.98μF
Filter Inductance	4.558mH
Inverter rating	1140kW

IV. Load Profile Input

The village loads are consumed for the households and the communal applications. There are 2300 households and the population is about 9820. The existing Biomass (Rice-Husk) power plant can supply 500 households and the SHS (Solar Home Systems) are installed in 100 households. The remaining 1400 households are un-electrified. Therefore, in this HOMER model, the PV Hybrid system is considered to supply the whole village.

The households are divided into low income, medium income, and high income households. These loads (kW) are mentioned in Table 1.

TABLE IV. Household Types and Loads

| Household Types	Amount	Load (kW)
Low income	1300	208
Medium income	700	437.5
High income	300	256.5

The communal facilities include the schools (high, medium, and primary), the monasteries, the hospital, and the street lamps. These loads (kW) of the communal facilities are described in Table 2.

Then, the total load is about 950.32 kW for the whole village. Fig. 9 shows the load profile inputs. The annual average is 3.4 MWh/day and the peak load is 950 kW.

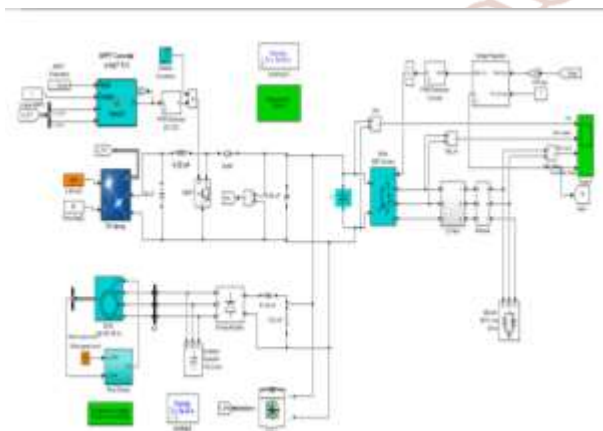TABLE V. Communal Facilities and Load

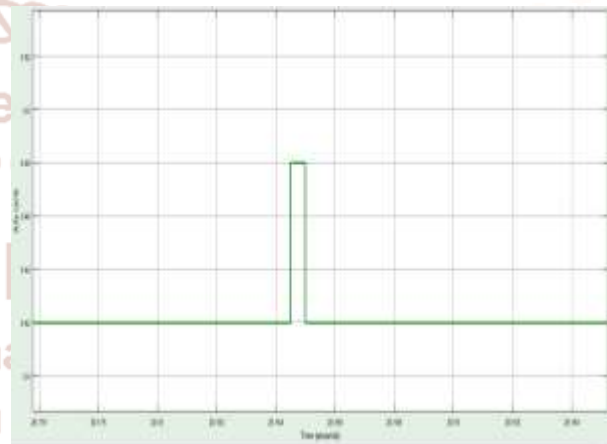| Communal Facilities	Amount	Load (kW)
School	3	10.17
Monastery	3	10.56
Hospital	1	3.59
Street Lamp	600	24

3. Simulation Results
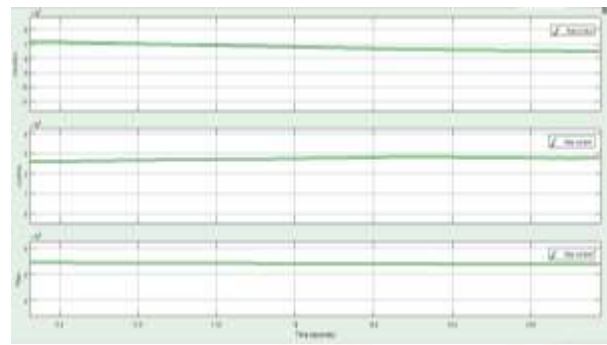
Figure(4) V_{pv} -I_{pv} -P_{pv} output curve

2. Proposed Solar-Wind Hybrid Model
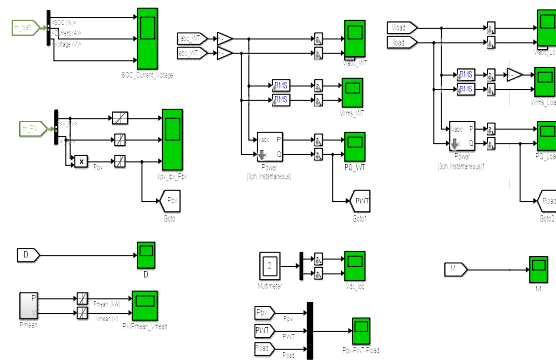

Figure(2) Solar-Wind Hybrid System of Matlab/Simulation
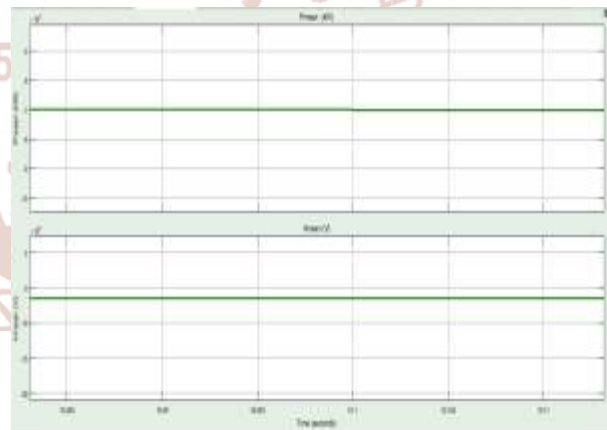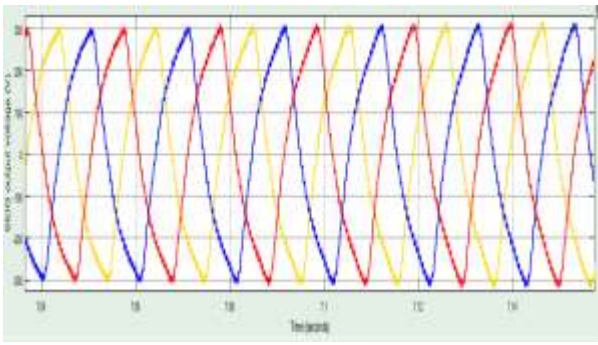

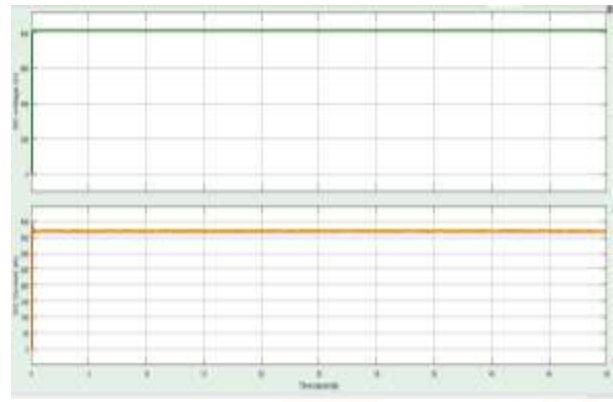Figure(5) Duty Cycle for MPPT Controller

Figure (3) Measurement System

Figure(6) P_{mean} and V_{mean} for PV

Figure(7)   Self Excited Induction Generator output voltage(WT)

Figure(10) V_{dc} and I_{dc} curve
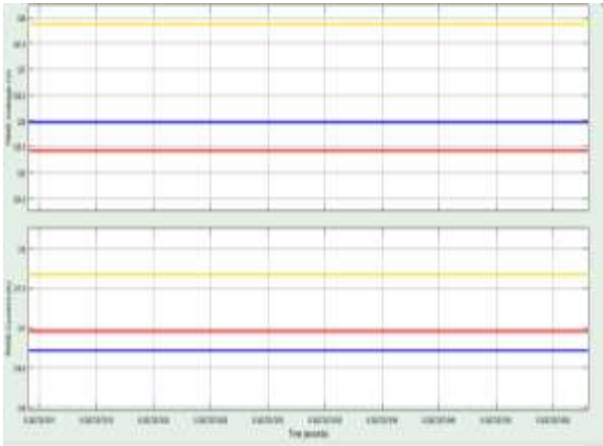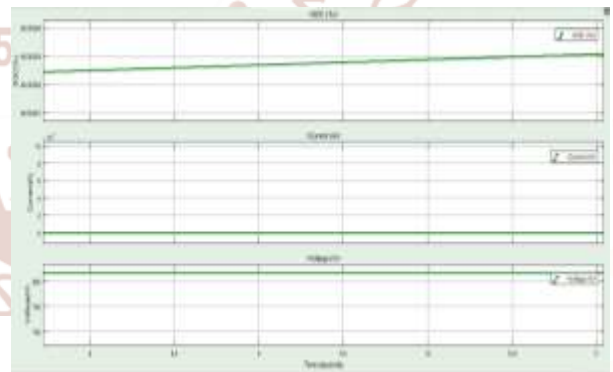

Figure(8) RMS Voltage and RMS Current for WT
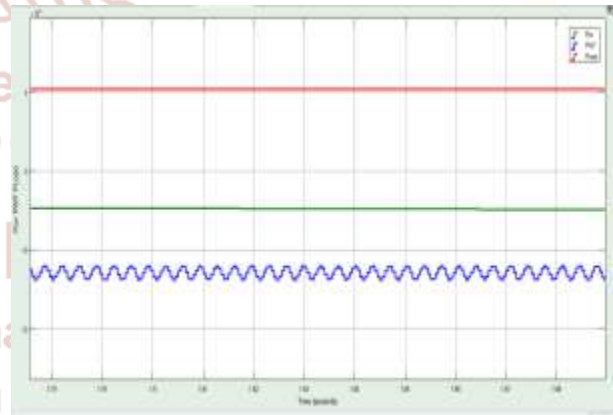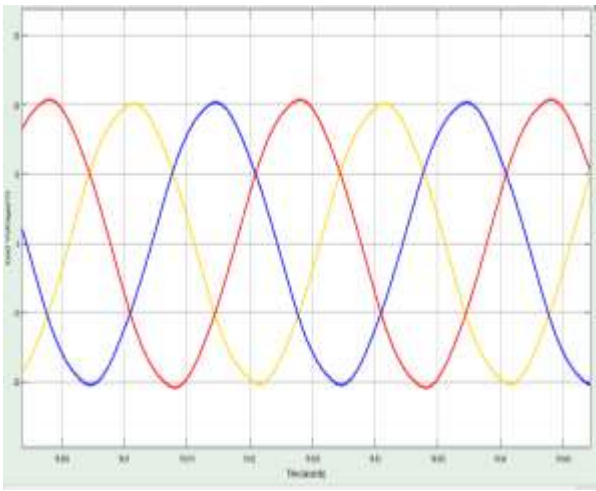

Figure(11) P_{pv}-P_{WT}-P_{load} curve
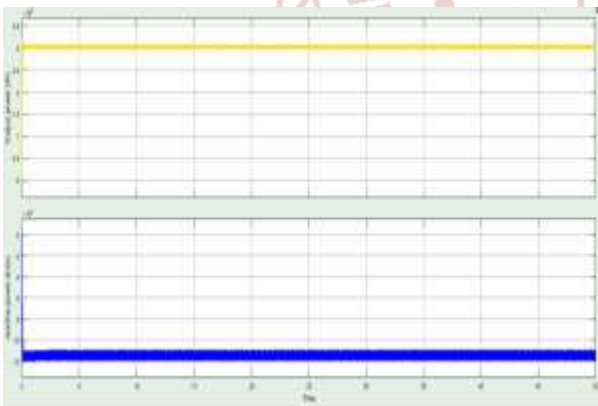
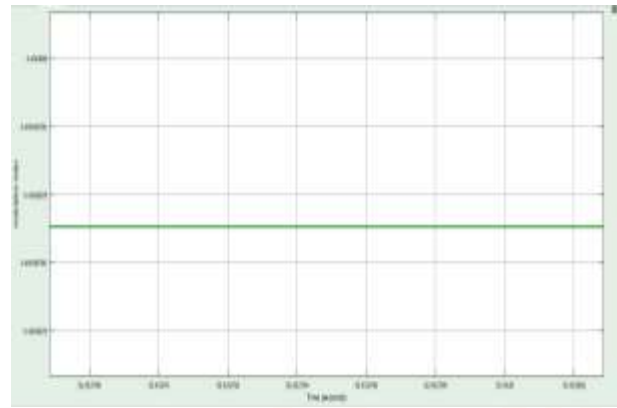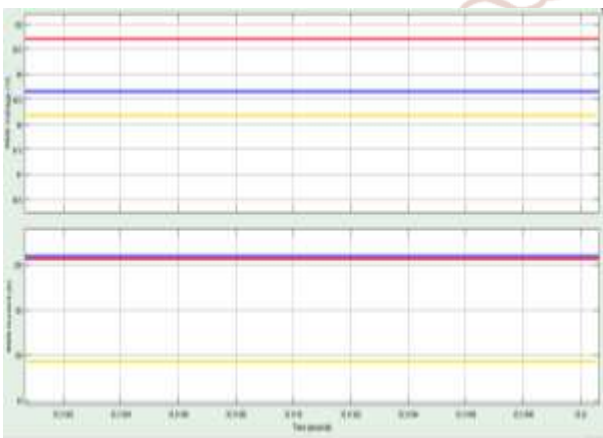Figure(9) Real Power and Reactive Power for WT
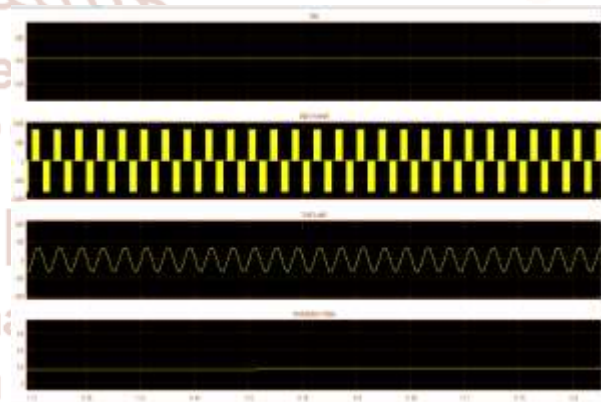

Figure(12) The State of Charge of the Battery

Figure(13 AC Output Voltage of the Load

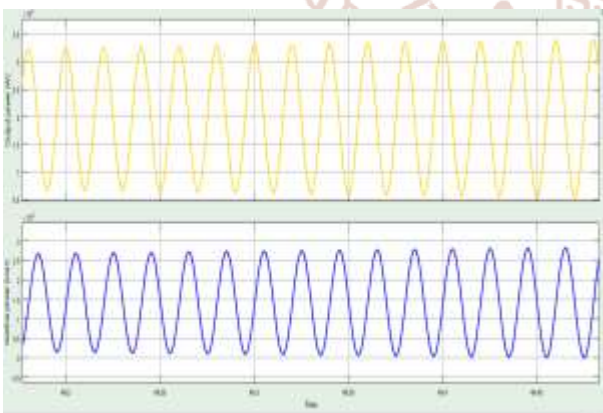Figure(14) RMS Voltage and RMS Current for Load

Figure(15) Real Power and Reactive Power for Load

Figure(16) Modulation Index for IGBT PWM Inverter

Figure(17) V_{dc} , $V_{ab\ inverter}$, $V_{ab\ load}$,modulation index

IV.CONCLUSION

Hybrid energy system significantly improves efficiency and sustainability of a power system. The penetration of renewable power sources, selection and combination of efficient energy to supply a remote community has been investigated in this work. In this study, a model is proposed for the supply of the demand having components PV array, Wind turbine, converter, battery bank and inverter. HOMER software simulated a number of configurations and the optimal solution is found. This study has been performed at specific region with variation in region, geographical condition, equipment cost and electricity tariff configuration can vary. This also gives a clean and a sustainable future.

REFERENCES

1) Bowman, M., Debray, S. K., and Peterson, L. L. 1993. Reasoning about naming systems. .

2) Ding, W. and Marchionini, G. 1997 A Study on Video Browsing Strategies. Technical Report. University of Maryland at College Park.

3) Fröhlich, B. and Plate, J. 2000. The cubic mouse: a new device for three-dimensional input. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems

4) Tavel, P. 2007 Modeling and Simulation Design. AK Peters Ltd.

5) Sannella, M. J. 1994 Constraint Satisfaction and Debugging for Interactive User Interfaces. Doctoral Thesis. UMI Order Number: UMI Order No. GAX95-09398., University of Washington.

6) Forman, G. 2003. An extensive empirical study of feature selection metrics for text classification. J. Mach. Learn. Res. 3 (Mar. 2003), 1289-1305.

7) Brown, L. D., Hua, H., and Gao, C. 2003. A widget framework for augmented interaction in SCAPE.

8) Y.T. Yu, M.F. Lau, "A comparison of MC/DC, MUMCUT and several other coverage criteria for logical decisions", Journal of Systems and Software, 2005, in press.

9) Spector, A. Z. 1989. Achieving application requirements. In Distributed Systems, S. Mullender