DESIGN CONSIDERATION OF RENEWABLE ENERGY SOURCES COORDINATION WITH RELIABLE DISTRIBUTION SYSTEM

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Abstract: Power System reliability is one of the most important aspects in the power system operation. Electricity interruption may cause high damage to consumers. To measure system, the electric utility industry has developed several performance measures of reliability indices which include outage duration, frequency of outages and system availability. To be reliable distribution system, load fluctuation can be reduced by equaling the fluctuated load and generated power from the renewable energy sources. In this paper, design consideration of renewable energy sources coordination with distribution system for 24hours by using a real-time switching power management to control supply and demand power, for minimizing the active power loss and power outage. The simulation for the proposed reliable distribution system is demonstrated by MATLAB in different condition and the simulation results are analyzed for a case of fluctuated industrial loads in Myanmar. In the study area, reliability efficiency is 0% when breakdown condition. According to the results, the stability is greatly improved by 54.79%. The proposed model and methods are applicable to not only Industrial zone which have conventional distribution system but also emergency load condition in which priority consumer loads.

Key Words: Photovoltaic system, Biomass Generation System, Reliability Indices, real radiation data, Matlab, demand side management

1. INTRODUCTION:

Continuous electric power supply is essential for modern living. A key function of a power system is to supply customers with electrical energy as economically and reliably as possible. Electrical service interruption can have a profound economic impact on certain customers. Any interruption in availability of electricity causes major disruption in people lives. The level of disruption is a function of dependency of people on electricity, which can be very high for a developed country and not as much for developing countries. Interruption can be planned or forced. If the available supply is not enough to meet the demands, the utilities have to implement rolling blackouts.

Forced interruptions are due to failures in the system caused by:

- Intrinsic factors, such as age of equipment, manufacturing defects,
- Environmental factors, such as trees, birds/animals, wind, lightning, ice,
- Human factors, such as vehicular accidents, accidents caused by utilities or contractor work crew, vandalism, etc.

Utilities can minimize the forced interruptions with proper design and maintenance of the system; however, it is impossible to avoid interruptions completely. It is worth noting that, the causes of incorrect behavior of protection and control systems, and that of circuit breakers are somewhat more complicated. Utilities commonly use indices such as System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Duration Index (CAIDI), Customer Average Interruption Frequency Index (CAIFI), Customer Interrupted per Interruption Index (CIII) and Average Service Availability Index (ASAI) to track reliability of their distribution system [9]. Computation of these indices requires complete log of all the interruptions. In addition to time, duration, protective device operation, and number of customers interrupted, the utilities also record the likely cause of outage and weather during outage. Utilities have been using their own procedures including the list of causes of outages for recording data on interruption [9]. Recently there has been some effort to standardize the reporting procedures. Attributing an outage to a specific cause is a subjective process and thus prone to error. In many cases if no evidence is present for an outage, the linemen report the cause of outage as unknown or other. Renewable energy technologies are utilized throughout the world for “clean energy” as the concerns for the impact of non-renewable energy extraction and the use on the environmental increases. The size and clean energy technology, renewable energy sources can be installed in close proximity to end-use consumers [1]. My study area is Industrial Zone 1 in Mandalay, which energy requirement per day is 282.4MWh, total energy supply from utility grid per day is 234.1MWh, needed renewable energy is 48.3MWh and the maximum demand is 20MW. To improve the reliability of existing distribution network, two renewable energy sources are employed in this system. The proposed system can provide the much needed electricity in industrial Zone1for basic loads as lighting. In this work, reliability, economics, and expected life are taken into consideration.

2. RELIABLE DISTRIBUTION SYSTEM:

Reliability assessment is of primary importance in designing and planning distribution system that operates in economical manner with minimal interruption of customer loads. The purposed model consists of photovoltaic generation system, biomass generation system with battery as storage system for peak load condition. Hence, before designing the system, certain parameters like solar irradiation, municipal solid wastes and load profile must be evaluated. It is presented in the following sections.

2.1. Load Details

Load is an important consideration in any power generating system. The entire system design is based on the size of the load. The loads influence on every aspect of efficiency and reliability of the system. Power needed by a load, as well as energy required over time by that load, is important for system sizing. In this case study, we have considered the Industrial Zone 1 from Mandalay, which is not access efficient electricity supply only from the utility grid. The total daily load average is 281MWh/day. The peak load requirement decides the size of the system. Here peak load consumption is 20MW. Figure 1 shows the daily load profile for the selected date of the study area.

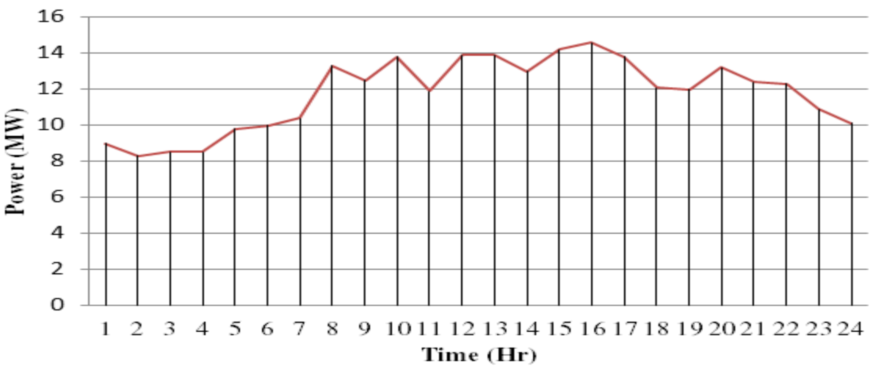


Fig. 1 Daily Load Profile for the Industrial Zone 1

2.2. Reliability Indices

A distribution system is one of the main three parts of a power system, responsible for transferring electrical energy to the end users compared with generation and transmission parts. However, analysis of the customer failure statistics of most utilities indicates that the distribution system makes the greatest individual contribution to the unavailability of supply to a customer In order to reflect the severity or significance of system outages, customer indices are evaluated.

$$SAIFI = \frac{\text{total number of customer interruptions}}{\text{total number of customer served}}$$

$$= \frac{\sum \lambda_i N_i}{\sum N_i} \text{ f/customer/yr} \quad (1)$$

$$SAIDI = \frac{\text{sum of customer interruption duration}}{\text{total number of customer}}$$

$$= \frac{\sum U_i N_i}{\sum N_i} \quad \text{hr/ customer /yr} \quad (2)$$

$$CAIDI = \frac{\text{sum of customer interruption duration}}{\text{total number of customer interruptions}}$$

$$= \frac{\sum U_i N_i}{\lambda_i N_i} \text{ hr/customer/yr} \quad (3)$$

$$ASAI = \frac{\text{Customer Hours Service Availability}}{\text{Customer Hours Service Demands}} \quad (4)$$

$$= = \left[1 - \frac{\sum U_i N_i}{Ni \times Ti}\right] \times 100$$

by using historical outage data recorded in distribution outage reports. This is important so that utilities know how their systems are performing, but is less useful when the specific impact of various design improvement options wish to be quantified and compared. To make such comparisons, a model must be developed which is capable of predicting reliability measures based on system topology, component reliability data, and operational da ta. Where $L_{a(i)}$ is average load demand at load I and U_i is outage time at load point i. Reliability indices are useful for determining what a customer can expect in terms of interruption frequencies and durations. Reliability indices are typically computed by utilities at the end of each year. In this Industrial zone has a total of 7,000 customers. Power Outage hours per year is 133.52 hours and the total number of customers interrupted is 205. Therefore, the reliability indices for Industrial Zone 1 is shown in table 1.

Table I Reliability Indices of Industrial Zone One.

	Industrial Zone One
SAIDI	8011.2 min per customer
SAIFI	1
CAIDI	8011.2 min per interrupted customer
ASAI	99.98%

2.3 Biomass Generation System

Biomass comprises of wood chips and wastes from wood industry, agricultural and forest residues, animal wastes, kitchen wastes and energy crops if available. Biomass undergoes anaerobic fermentation to produce biogas in community scale or household scale biogas digesters. Biogas is used as fuel to generate power from engine-generator set. In this system, biomass generator is used municipal solid waste. The average municipal solid waste available in study area is 450 tonnes per day[4].By using municipal solid waste for electricity production, study area will be clean, environmental impact will be reduce and there is no need for fuel .

Table II The Composition of The Solid Wastes

Component	**Percentage**
Dry Waste	30%
Wet Waste	70%

The components of dry wastes can be further classified as shown in table 2.

Table III The Components of The Dry Waste

Dry Waste Component	**Percentage**
Paper	8%
Plastic	7%
Metal	9%
Glass	6%
Debris/Sand	5%

2.3.1 Calculation for Biomass Generation Output Power

The following two models can be used for energy conversion

(i) From dry solid waste (30%)

(ii) From wet solid waste (70%)

Overall waste generated is 450Tons (408,50Kg)

Dry solid waste [Dry –MSW] = [0.3 x Overall waste]Kg

Wet solid waste [Wet- MSW] = [0.7x Overall waste] Kg

A. Power generation from dry solid wastes

Total solid waste generated (TSW) = 122445 Kg

Net Calorific value (NCV) = 900 kcal / kg

Energy recovery potential (ERP) =NCVxTSWx1.16 $^{x10-3}$

Power generation potential (W) =EPR /24

Conversion efficiency = 25%,

Net Power generation = 1.331MW

B. Power generation from wet solid wastes

Total waste quantity organic / volatile solids = 285,705 Kg

Organic biodegradable fraction (33%) = 94282.65Kg

Typical digestion efficiency (60%) =56569.59Kg

Typical biogas efficiency (B) = 0.8 x fraction destroyed

Net Calorific value (NCV) of biogas = 5000 Kcal/ m^3

Energy recovery Potential (MWh) = NCVxB x1.16 $x10^{-3}$

Power generation potential = NCVxBx1.16 x 10^{-3} /24

Conversion efficiency = 30%

Net power generation = 3.282 MW

Total power generated from both dry and wet wastes (W)

= P(dry)+ P(Wet)

= 1.331+ 3.282

= 4.61 MW

=4 MW(Assume)

2.4. Photovoltaic Generation System

A photovoltaic generator is the device that generates electrical energy as a result of the photovoltaic effect that is the electrical potential developed between two semiconductor materials when their common junction is illuminated with radiation of photons. The basic building element of a photovoltaic (PV) generator is the PV cell, also referred as solar cell [4].

An ideal solar cell may be modeled by a current source in parallel with a diode; in practice no solar cell is ideal, so a shunt resistance and a series resistance component are added to the model. The resulting equivalent circuit of a solar cell is shown on the Fig. 1.

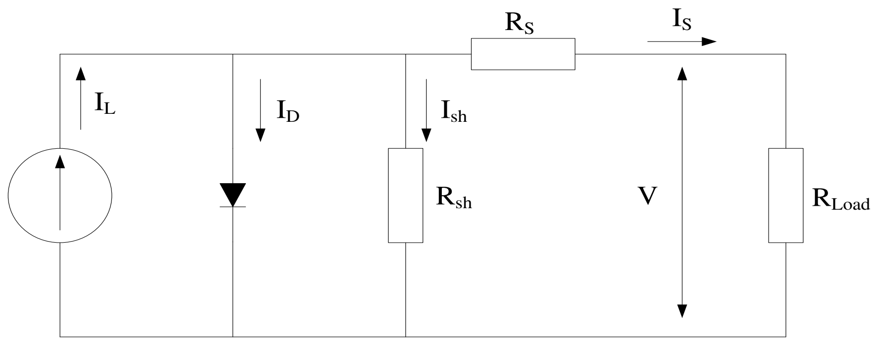


Fig 2. Electrical Equivalent Circuit for PV Module
Source: [4]

2.4.1. Setting Constant Values and Defining PV Module Parameters

For the modeling and simulation of PV module, the following constant values are set as constant parameters.
Reference Temperature (Tcref) = 298 K
Reference Isolation (Gref) = 1000 W/m^2
Boltzmann's Constant (K) = 1.37×10^{-23} J/K
Electronic Charge (q) = 1.602×10^{-19} C
Bandgap Energy (Egref) = 1.12 eV for Silicon
Constant (C) = 0.0002677 for Silicon

The module parameters are to be set according to the selected module. In this thesis, the module parameters are set according to manufacturer data sheet of selected module as follow:
Open circuit voltage (Voc) = 45.1 V
Short Circuit Current (Isc) = 8.99 A
Number of Series Cells (Ns) = 72numbers
Ideality Factor (n) = 1.36
Series Resistance (Rs) = 0.18 Ω
Short Circuit Coefficient (uIsc) = 0.00434
Equation which define the model of a PV cell are given below

$$V_t = \frac{k T_{op}}{q} \quad (5)$$

$$V_{oc} = V_t \ln\left(\frac{I_{ph}}{I_s}\right) \quad (6)$$

$$I_d = \left[e^{\frac{(V+IR_S)}{(nV_t C N_S)}} - 1 \right] I_S N_p \quad (7)$$

$$I_s = I_{rs} \left(\frac{T_{0p}}{T_{ref}}\right)^3 e^{\left[\frac{qE_g}{nk}\left(\frac{1}{T_{op}} - \frac{1}{T_{ref}}\right)\right]} \quad (8)$$

$$I_{rs} = \frac{I_{sc}}{\left[e^{\left(\frac{V_{oc}\,q}{KCT_{op}\,n}\right)-1}\right]} \quad (9)$$

$$I_{sh} = \frac{V + IR_s}{R_p} \quad (10)$$

$$I_{ph} = G_k \left[I_{sc} + K_I (T_{op} - T_{ref})\right] \quad (11)$$

$$I = I_{ph} N_p - I_d - I_{sh} \quad (12)$$

Where,

I_{ph} is the short circuit current

I_s is the reverse saturation current of diode (A),

q is the electron charge (1.602×10^{-19} C),

V is the voltage across the diode (V),

K is the Boltzmann's constant (1.381×10 -23 J/K),

T is the junction temperature in Kelvin (K).

N is theIdeality factor of the diode

R_s is the series resistance of diode,

R_{sh} is the shunt resistance of diode,

STC is he Standard Test Condition,

G = 1 KW/m^2 at spectral distribution of AM = 1.5,

T_{op} = 25°C
G_K is the Solar irradance ratio

V_t ; Thermal voltage, v
K ; is the Boltzmann's constant (1.381×10^{-23} J/K),

T_{op}; Cell operation temperature in °C
T_{ref} ; Cell temperature at 25°C
q; Electron Charge constant (1.602×10^{-19} C)

I_s ; Diode reversed saturation current, A

I_{rs} ; Diode reversed saturation current at T_{op}

I; Output current from the PV pannel, A

I_{sh} ; Shunt current, A

V; Output voltage from the PV pannel, V

n; Diode ideality factor, 1.36

C; No of cells in a PV panel, 72

N_s, N_p; No of PV panel in series & parallel

E_g ; Band-gap energy of the cell. 1.12 ev

A.M is the Air mass coefficient

Detailed Model for PV Module and Simulink Model for PV Module are shown in Figure 4.

Total Photovoltaic Power =33.81 MWh/Sunshine hr/day

=33.81/8.11

=4.168 MW

=4MW (Assume)

3. SIMULINK MODEL OF THE COORDINATION DISTRIBUTION SYSTEM:

In the proposed system, energy required per day is 281.4MWh, total energy supply from utility grid per day is 185MWh and needed renewable energy is 96MWh.Modelling and design consideration of renewable energy sources: photovoltaic and biomass generator using municipal solid waste coordination to the distribution system to supply the priority loads. Figure 3 shows the Simulink model for the proposed coordination system.

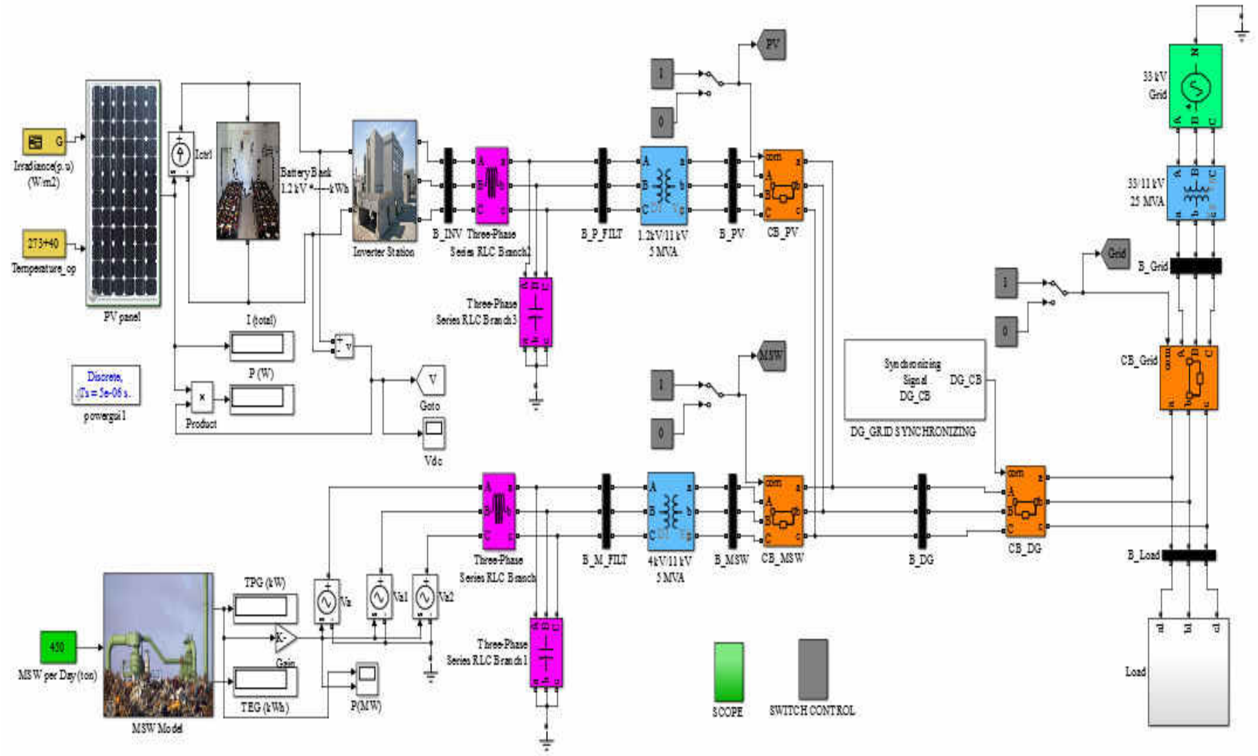
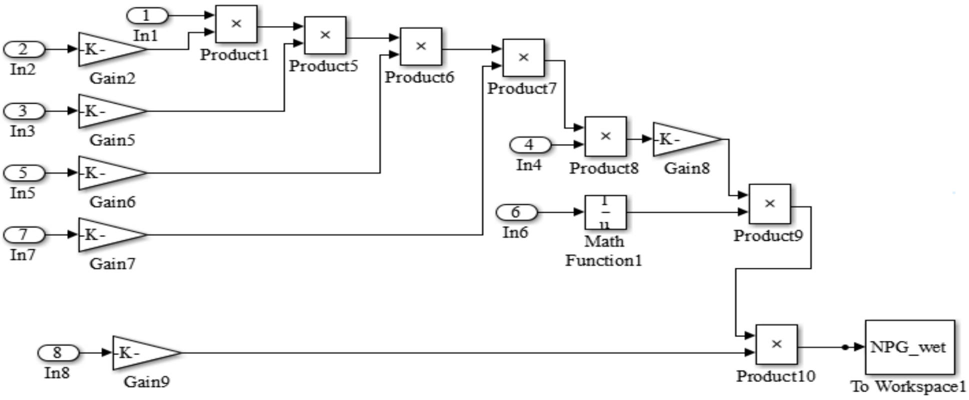


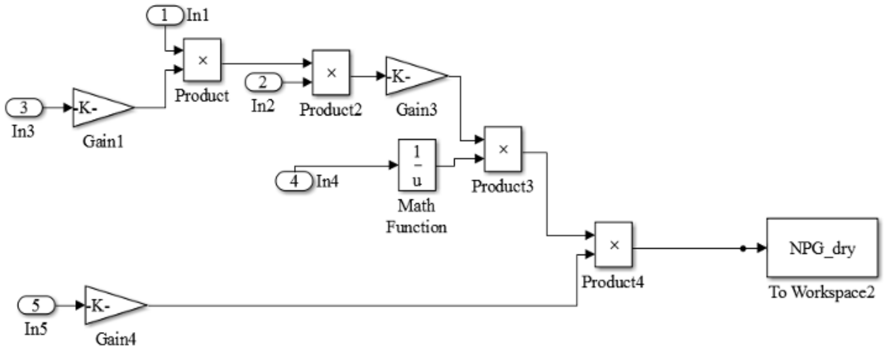
Fig.3 Simulink Model for the Proposed Coordination System

3.1 Simulink Modelling of Biomass Generation System

For the modelling of biomass generation system, matlab /Simulink software package is utilized. The Simulink model for selected biomass generation system is shown in Figure 7.



(a)



(b)

Fig 5.Simulink Model for Selected Biomass Generation

System: (a) Subsystem Structure of MSW (WET) (b) Subsystem Structure of MSW (DRY)

3.2 Simulink Modelling of PV Module

For the modelling of PV module, matlab/Simulink software package is utilized. In the Simulink modelling, the simplicity and accuracy is taken as primary concern. The proposed model is also flexible for the modification of PV module parameters and environmental condition.

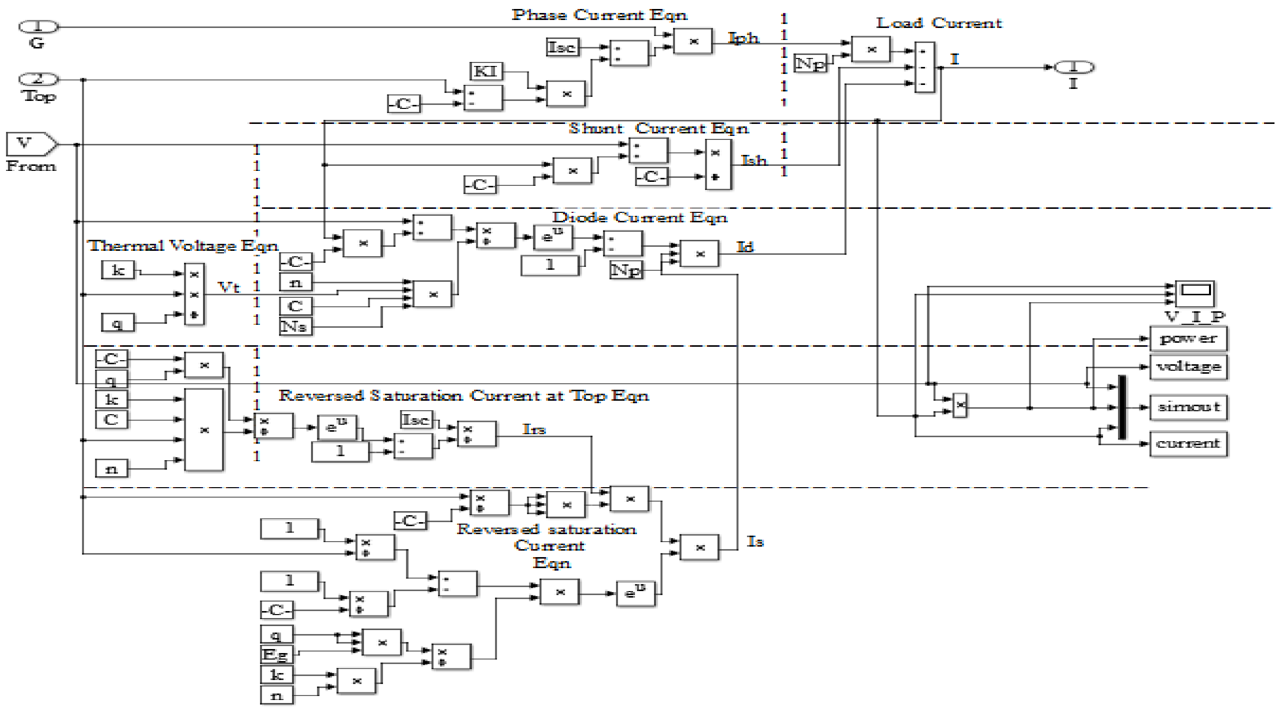


Fig 4. Simulink Model for Selected PV Module

4. SIMULATION RESULTS:

To evaluate the performances of the supporting renewable energy sources coordination to distribution system are created as follows:

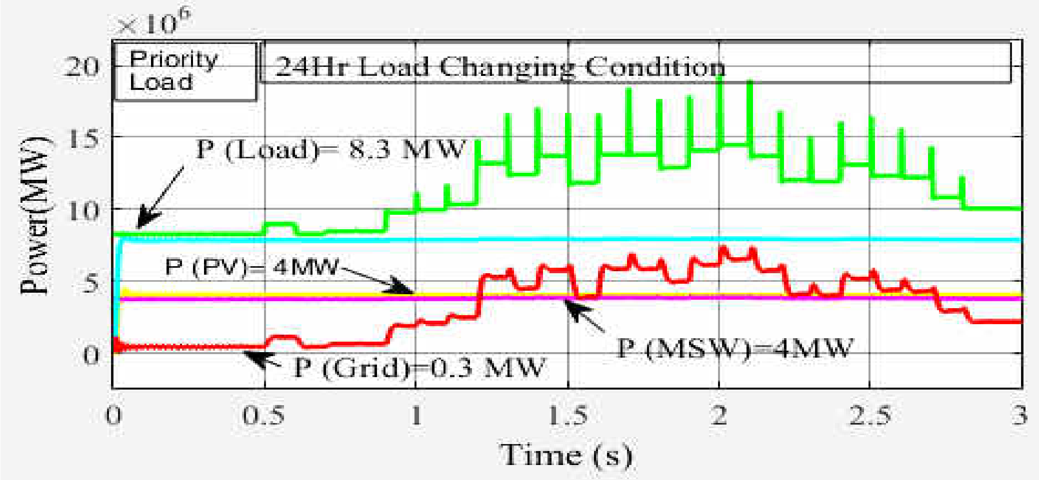


Fig.6 Simulation Results of the Proposed System Supply Power

The active power measurement for grid and renewable energy sources coordination condition is shown in Fig 14. Within 0s to 0.5s, the minimum power development by photovoltaic supply system is 4MW, biomass supply system is 4MW grid supply is 0.3MW and the active power consumed by the load is 8.3MW.This is based power for the priority load of Industrial Zone 1.In this Simulink model, we investigated as time (24hr) as time duration (from 0.5 sec to 3 sec).In the coordination system, photovoltaic and biomass system is supplied priority load or minimum load 8MW.Another needed demand power is supply by grid as the chaining with daily load in Fig 1. Simulation results of the coordination system are shown in table 4.

Table IV Simulation Results of Coordination System

Hour (hr)	Times Durations(sec)	Load Consume Power (W)	PV Supply Power (W)	Biomass Supply Power (W)	Grid Supply Power (W)
1 AM	From 0.5 to 0.6 sec	9 MW	4MW	4MW	1MW
2 AM	From 0.6 to 0.7 sec	8.3 MW	4MW	4MW	0.3MW
3 AM	From 0.7 to 0.8 sec	8.5 MW	4MW	4MW	0.5MW
4 AM	From 0.8 to 0.9 sec	8.5 MW	4MW	4MW	0.5MW
5 AM	From 0.9 to 1 sec	9.8 MW	4MW	4MW	1.8MW
6 AM	From 1 to 1.1 sec	10 MW	4MW	4MW	2MW
7 AM	From 1.1 to 1.2 sec	10.4MW	4MW	4MW	2.4MW
8 AM	From 1.2 to 1.3 sec	13.3 MW	4MW	4MW	5.3MW
9 AM	From 1.3 to 1.4 sec	12.5 MW	4MW	4MW	4.5MW
10 AM	From 1.4 to 1.5 sec	13.8 MW	4MW	4MW	5.8MW
11 AM	From 1.5 to 1.6 sec	11.9 MW	4MW	4MW	3.9MW
12AM	From 1.6 to 1.7 sec	13.9 MW	4MW	4MW	5.9MW
1PM	From 1.7 to 1.8 sec	13.9 MW	4MW	4MW	5.9MW
2 PM	From 1.8 to 1.9 sec	13 MW	4MW	4MW	5MW
3 PM	From 2 to 2.1 sec	14.2 MW	4MW	4MW	6.2MW
4 PM	From 2.1 to 2.2 sec	14.6 MW	4MW	4MW	6.6MW
5 PM	From 2.2 to 2.3 sec	13.8 MW	4MW	4MW	5.8MW
6 PM	From 2.3 to 2.4 sec	12.1 MW	4MW	4MW	4.1MW
7 PM	From 2.4 to 2.5 sec	12 MW	4MW	4MW	4MW
8 PM	From 2.5 to 2.6sec	13.2 MW	4MW	4MW	5.2MW
9 PM	From 2.6 to 2.7 sec	12.4 MW	4MW	4MW	4.4MW
10 PM	From 2.7 to 2.8sec	12.3 MW	4MW	4MW	4.3MW
11 PM	From 2.8 to 2.9 sec	10.9 MW	4MW	4MW	2.9MW
12 PM	From 2.9 to 3 sec	10.1 MW	4MW	4MW	2.1MW

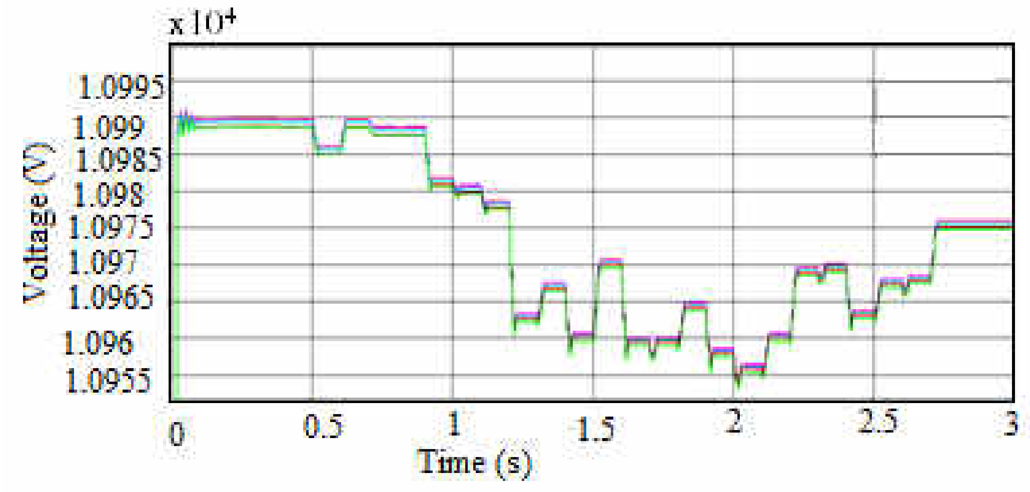


Fig.7 Simulation Results of the Proposed System Supply Voltage

In the voltage measurements at all conditions, the generation bus exhibits 11kV and the load bus shows 11kV in Fig7.

5. CONCLUSION:

This paper proposed a novel approach to study the renewable energy sources coordination on distribution system reliability by using the MATLAB/ Simulink program. The effect on system reliability of each component can be clearly presented. For extended load, renewable energy sources coordination system is more economical and reliable. For increasing condition of load, the coordination of renewable energy sources with grid supply system is one of the solutions to reduce power losses and power outage. In this paper, the simulated results show the simulation models and results of distribution system with or without renewable energy systems by the daily load profile of Industrial Zone 1.With grid supply only condition, the results show that reliability indices are too sensitive to location. Without grid supply condition, renewable energy sources supplied 8MW that it is suitable for priority load of study area. With grid and renewable energy sources coordination condition, renewable energy sources supplied to fulfil needed of demand power. It is own supply system that it can be reduce the minute losses and improved reliability for the proposed system. It can provide the immediate solution for Industrial zones system can be used any place in Myanmar provided that the weather data and other input data are available. This study can increase our country electricity production base and also smoothening electricity supply.

ACKNOWLEDGMENT

The author would like to Dr. Wunna Swe, Professor and Head of Electrical Engineering Department, YTU, for his helpful and valuable suggestion and guidance in the preparation of the thesis. In particular I would like to thank Dr. Okkar Soe and Dr. Wint Wint Kyaw for invaluable guidance. I would like to thank all the teachers ,for their kindness, graceful, attitude and permission to do this paper. Finally, I would like to acknowledgement the love and support given to me by my parents.

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