# INTERNSHIP REPORT

# ON

# THE INTEGRATION OF POWER FROM RICE HUSK POWER PLANT INTO AN EXISTING WEAK GRID SYSTEM

By

**Rumana Tarin**

Submitted to the
Department of Electrical and Electronic Engineering
Faculty of Sciences and Engineering
East West University

in partial fulfilment of the requirements for the degree of
Bachelor of Science in Electrical and Electronic Engineering
(B.Sc. in EEE)

Summer, 2011

Approved By

Tahseen Kamal 03.10.2011

Academic Advisor

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# Approval Letter

**NRECA International Ltd.**
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February 17, 2011

Ref: 2001-043

Mr. M. Sayeed Alam
Assistant Professor & Deputy Director
Career Counseling Centre
East West University
Dhaka, Bangladesh

Subject: Completion of Internship Project Report- Ms Rumana Tarin
Ref: Memo No. EWU (CCC) 05/10-319, Dated August 17, 2010

Dear Mr M. Alam

NRECA International Ltd.'s work in Bangladesh is related to providing technical assistance to the Rural Electrification Board (REB) through funding from primarily the US Agency for International Development (USAID) and others donor agencies. Their involvement in Bangladesh has been since the inception of the REB in 1977. This office also supports other projects in the South Asia region as well as in Africa and the Middle East. NRECA International Ltd., headquartered in Arlington, VA, USA is a wholly-owned subsidiary of National Rural Electric Cooperative Association (NRECA), which is the national association of electric cooperative in the USA with over 1000 members providing electric services to more than 35 millions rural consumers in forty-seven states.

On behalf of NRECA International Ltd, we are pleased to inform you that Ms. Rumana Tarin has successfully completed her internship project assignment under supervision and guidance of NRECA. In fulfillment of the assignment obligations, Ms. Rumana Tarin submitted her project report to NRECA.

Throughout Ms. Rumana Tarin's association with NRECA, she has been found to be industrious, intelligent, and her pleasant personality makes her easy to work with.

I wish her every success in her future endeavors.

If you have any questions please feel free to contact Mr. Md Hasibur Rahman at 0171-402-0278 or Md. Maruf Hasan at 01817579825.

Yours Sincerely,

James M. Ford
Country Director
NRECA International Ltd

**NRECA Home Office**: 4301 Wilson Boulevard, Arlington, Virginia 22203-1860, Tel: (703) 907-5500, Fax: (703) 907-5532, Web: www.nrecainternational.org

# Acknowledgement

This work has been carried out in the Department of Electrical & Electronic Engineering, East West University (EWU). The software support provided by the National Rural Electric Cooperative Association (NRECA) International Ltd. is gratefully acknowledged.

I would like to extend my gratitude and sincere thanks to my supervisor Ms.Tahseen Kamal, Dept. of Electrical & Electronic Engineering, , East West University (EWU) for her constant inspiration and support during the course of my internship.I truly appreciate and value her esteemed guidance and theoretical support from the beginning to the end of this internship, and valuable discussions.

I would also like to mention the name of Dr. Anisul Haque, Chairperson and Professor of the Dept. of Electrical & Electronic Engineering, East West University (EWU) for being so kind during the period of my internship.

I express my gratitude to Mr. James Ford Country Director, NRECA and Mr Hasibur Rahman, Project Engineer of NRECA International Ltd, for their valuable suggestions, discussions, and constant encouragement all through the internship work. I am indebted to them for having helped me to shape the problem for providing insights towards the solution.

Many thanks go to ATM Selim for providing a GIS map of Dinajpur PBS and Zillur Hossain for valuable discussions and time saving collaboration with practical field data.

Finally, I would like to thank my family for their love and support. I wish to express my gratitude to my parents, whose love and encouragement have been a great support throughout my education.

# Executive Summary

This under graduate internship deals with the integration of power from rice husk power plant into an existing weak grid system. The aim of this internship is to develop and analyse a model of the power system considering husk power generation and integration with rural sub-transmission grid.

Power generation from rice husk energy has gained popularity in recent years all over the world, mainly because husk energy is renewable and eco-friendly. This internship has been completed to find the impact study of connecting a 5*1-MW power generation from husk into the 33kV-sub transmission system of a utility company within the north-west part of Bangladesh. There are a total of 104 rice mills within 5 km of Dinajpur town. Rice mills in this area operate only 6 months out of the year. Husk is available at prices ranging from 2.3Tk/kg during the off season down to 3Tk/kg during peak husking season. In this internship it is found that steady state voltage changes are generally the factor which restricts the amount of power that can be connected at a certain point in the grid provided there is no restricted access in the transfer capacity. Reactive power control strategy can be used to integrate more power in the grid if the voltage limits are the deciding factor.The simulation result shows that it is possible to add a power generating subsystem in the weak grid to improve loadshedding.

# Training Schedule

| Date | Section/Task | Duration | Contact Person |
|---|---|---|---|
| Sept. 15 to Sept. 30 | Power System Basics | 20 hours | Md Maruf Hasan<br>Project Engineer, NRECA |
| Oct. 1 to Oct. 20 | Power System Analysis | 40 hours | Md Maruf Hasan<br>Project Engineer, NRECA |
| Oct. 21 to Oct. 31 | Power System Analysis<br>Milsoft Software Training | 30 hours | Hasibur Rahman<br>Project Engineer, NRECA |
| Nov. 1 to Nov. 30 | Modeling of Electrical Network and Analysis | 50 hours | Hasibur Rahman<br>Project Engineer, NRECA |
| Dec. 1 , 2010 to Jan. 31, 2011 | Report Writing | 50 Hours | Hasibur Rahman<br>Project Engineer, NRECA |

# Table of Contents

**Section** **Page**

# List of Figures

# List of Tables

# Chapter 1 Introduction

In Bangladesh, the demand for electricity is increasing day by day. Bangladesh has huge shortage of power generation, particularly at peak demand periods. The result is daily load shedding during peak times throughout all electric utilities in Bangladesh. For economic emancipation and in order to meet the Millennium Development Goals, the electricity growth that is generating more electricity, building more transmission/distribution capacity, bringing more area/ population under electricity coverage and ensuring more efficient management of these are the essential issues.

Biomass power from rice husk can be considered as potential renewable energy resources to fulfil the power shortage in the northern region of Bangladesh. Because of the rapid increase in demand for power, utilities with significant Biomass resources potential in their service territories need to perform studies of the technical and economic impacts of incorporating Biomass generation plants into their systems.

Green power resources can be managed in Bangladesh through proper plant interconnection, integration, transmission planning, and system and market operations. These requirements convinced to do the undergraduate internship on Power Sector

## 1.1 Company Profile

The unergraduate internship has been done with NRECA International Ltd. NRECA International Ltd., headquartered in Arlington, VA, USA is a wholly-owned subsidiary of National Rural Electric Cooperative Association (NRECA), which is the national association of electric cooperative in the USA with over 1000 members providing electric services to more than 35 millions rural consumers in forty-seven states. NRECA International has developed and implemented rural electrification programs in over 42 countries with generous funding support from USAID, U.S. Department of Agriculture, and other bilateral and multilateral international organizations such as the World Bank, the U.K. Department for International Development (DFID), Asian Development Bank (ADB) and host country government agencies. These programs have resulted in increased agricultural productivity, millions of new jobs in micro and small enterprises, and higher incomes and quality of life for more than 100 million people.

NRECA's work in Bangladesh is related to providing technical assistance to the Rural Electrification Board (REB) through funding from primarily the US Agency for International Development (USAID) and others donor agencies. Their involvement in Bangladesh has been since the inception of the REB n 1977. NRECA s Dhaka office also supports other projects in the South Asia region as well as in Africa and the Middle East. NRECA International has served as the primary technical advisor to the rural electrification program and provides technical assistance through funding from USAID and the Department for International Development (DFID) of the United Kingdom.

Also ongoing, is the Rural Energy Development Program (REDP), a joint initiative between the UK Department for International Development s (DFID), USAID and NRECA International. The first and primary task is the overall supervision and monitoring of the DFID funded REDP project, to verify that the execution of the project is in accordance with REB standard procedures, and to monitor and approve the expenditure of funds. The second task is to assist REB and PBSs in the development and implementation of programs that would help strengthen the PBS concept (based upon the U.S. rural electrification cooperative model) through improved member education and the development of the 70 PBS Boards of Directors. The final task is an assessment to determine the socio-economic impact of the DFID project funding on the targeted program beneficiaries.

The Bangladesh rural electrification program is the most successful program in South Asia and one of the most successful in the world. The program was initiated in 1977 with the creation of the Rural Electrification Board (REB) and several electric cooperative pilot projects. It has led to the establishment of 70 electric distribution cooperative societies that deliver power to more than 45 million people.

**Program Accomplishments**

- 70 electric cooperatives are now operational
- Approximately 48,700 rural villages have been electrified
- Over 45 million people in rural areas have electricity service
- 223,800 km of distribution lines and 426 substations have been constructed
- Average system loss for all PBSs is 12% and bill collection is over 97%
- Total cumulative program funding of $1.4 billion from 20 donors

## 1.2 Origin of the Internship Report

In this internship, first a feasibility study of the husk power plant was conducted based on available NRECA study report  Biomass Resource Assessment for PBS Power Supply  and other research data. Then necessary work was carried to develop the model of the utility including existing service grid interconnection with the test distributed rice husk power generation plant to serve small town and group of villages.

## 1.3 Objective of the Internship

Based on the need for knowledge of the interaction between the grid and green power generation plant installations, the internship is designed with the following objectives:

1. Theoretical review of basic stages and components of the Biomass Plant to obtain and analyse the most common systems used today and those planned for the near future.
2. Development of an electric model for the case study of 33kV network of the Dinajpur PBS-1 service territories using Milsoft engineering analysis software.
3. Development of a computer simulation tool to integrate Biomass power generation plant into the PBS 33 kV grid.
4. Development of Matlab algorithm for load factor and load growth analysis for power system.
5. Power flow analysis of the integrated system to analyse the impact of distributed power generation on the voltage regulation of the existing grid.

## 1.4 Scope and Methodology of the Internship

The internship focused on development and analysis of a computer model for the Dinajpur PBS-1 Electric Utility distribution system in Bangladesh to integrate Biomass generation farm into the existing distribution network. This work is performed through modelling of a distribution system, development of methods for integrating distributed generation into the existing grid and analysis of methods for power system planning, control and operation.

Designing of the appropriate methodology for internship, being one of the most crucial tasks to accomplish, is multi-phased and rigorous. First the pre-feasibility study for the selected electric utility system with Biomass Power is conducted in this internship. Then power system performance and control algorithms are developed in coordination with a Biomass farm considering the availability of rice husk and the load. The methodology used for this analysis consists of the following elements:

- Preparation of a one- line electrical model for the 33kV network supplying power to service territories of the Dinajpur Electric Utility. This model is prepared using the GIS map for locating projected location for the rice husk generation farm and existing distribution substation.
- MILSOFT engineering analysis software used for analysing the performance of the developed model considering present peak loads. Performance is considered adequate if the distribution network can maintain a voltage of 102% of nominal value.
- MATLAB /SIMULINK software used for load factor, load forecasting and power system stability analysis.

# Chapter 2: Detail of Internship Work

## 2.1 Power Generation-Renewable vs. Conventional

### 2.1.1. A Brief History of Electric Power Systems

The availability of electrical energy is essential for the functioning of modern societies. It is the most accepted form of energy, because it can be transported easily at high efficiency and reasonable cost. It is used to provide the energy needed for transportation, operating information and communication technology, lighting, food processing and storage as well as a great variety of industrial processes, all of which are characteristics of a modern society.
The term  electric power system  is used to denote the entire electric network, which is composed of the four components (Levi, 2008):

- Generation
- Transmission
- Distribution
- Utilization

The first electric network in the United States was established in 1882 at the Pearl Street Station in New York City by Thomas Edison (Saadat, 2004). The power was generated by dc generators and distributed by underground cables. Due to excessive power loss, $RI^2$ at low voltage, Edison s companies could deliver energy only a short distance from their stations. The invention of the transformer (William Stanley, 1985) to raise the level of voltage for transmission and distribution made ac system possible. The Nikola Telsa invention of the induction motor in 1888 helped replace dc motors and hastened the advance in use of ac systems (El-Hawary, 2000). The first United States single-phase ac system was installed in Oregon in 1889. Southern California Edison Company established the first three phase 2.3 kV systems in 1893 (El-Hawary, 2000). Modern electric power systems have been developed, over the last fifty years (Simoes & Farret, 2004).

### 2.1.2. Green Energy vs. Conventional Energy Sources

There is an increased global demand for environmentally friendly power. Green energy is rapidly developing into a notable power source in many countries of the world. Electricity is generated in power plants, in which a primary energy source is converted into electrical power. Examples of widely used primary energy sources are fossil fuels, hydropower i.e. falling or flowing water and nuclear fission. These sources belong to the category of conventional sources (Levi, 2008). Fossil fuel and uranium reserves are basically finite. Further, a remarkable drawback of generating electricity from fossil fuels and nuclear fission is the undesirable environmental impacts, such as the greenhouse effect caused by the increase of the CO2 absorption in the earth s atmosphere and the nuclear waste problem. Hydropower is a clean electric energy source of renewable type. Hydropower plants convert the energy in flowing or falling water into electricity comprise a valuable alternative for thermal and nuclear power generation, because they do not have the drawbacks of finite primary energy source supplies and emissions and nuclear waste. However, the construction of dams and basins for hydro power generation causes the flooding of large areas and thus destroys local ecosystems and sometimes forces many people to move.

Energy from rice husk could be an attractive solution to world s energy demand because it is clean, infinite and commercially competitive with the new renewable energy technologies. The reason for the world wide interest in developing green generation plants is the rapidly increasing demand for electrical energy and the consequent diminution reserves of fossil fuels, namely, oil and coal. Further, other environmental impacts of green power are limited as well. Although they emit some smoke and noise, the consequences of this are small and ecosystems seem hardly to be affected.

### 2.1.3. Green Energy in Bangladesh

For fulfilling the requirements of both energy and the environment, renewable energy affords many countries the opportunity to reduce their dependence on fossil fuels. While many countries are keen to build large green farms, in Bangladesh, though there is some prospect of green farm development, very little work has been done for the full integration of large dispersed biomass power into the power grid. Total renewable power generation in Bangladesh is reported as 50 kW (Islam, 2005). It is 0.001% of total installed power of Bangladesh (4995 MW). Electricity power generation could be one promising renewable energy source that has created a lot of interest in Bangladesh and offers a large development potential.

This internship analyses the main technical challenges that are associated with the integration of husk power into power systems and its impact on a weak electric distribution grid. Future research directions for a better understanding of the factors influencing the increased integration of Biomass power into power systems are also given.

## 2.2 Internship Background Area

The internship focused on a power distribution service territory in Bangladesh named Dinajpur PBS-1 (Electric Distribution Utility), which is currently taking power from notational grid. The average peak demand of this utility is 40 MW (REB, 2008). As mentioned earlier, due to shortage of power generation, national grid can only supply 20 MW power to the Electric Utility during the peak demand period (REB load shedding Report-2009). This result is unexpected load shedding.

A possible solution to reduce the supply shortage and inadequate voltage problem at 33 kV network of Dinajpur PBS-1 from a planning standpoint would be installation of a distributed generation rice husk farm, as shown in Fig. 2.1, where a map of concentrated rice mills cluster is given. The map illustrates the proposed 5 MW rice husk generation plant that will be interconnected with distribution system. The developed model is used for different power system analysis studies which include

- effects of Biomass generation power on the power system,
- voltage regulation,
- power quality,
- power imbalances,
- and impacts on electricity distribution system

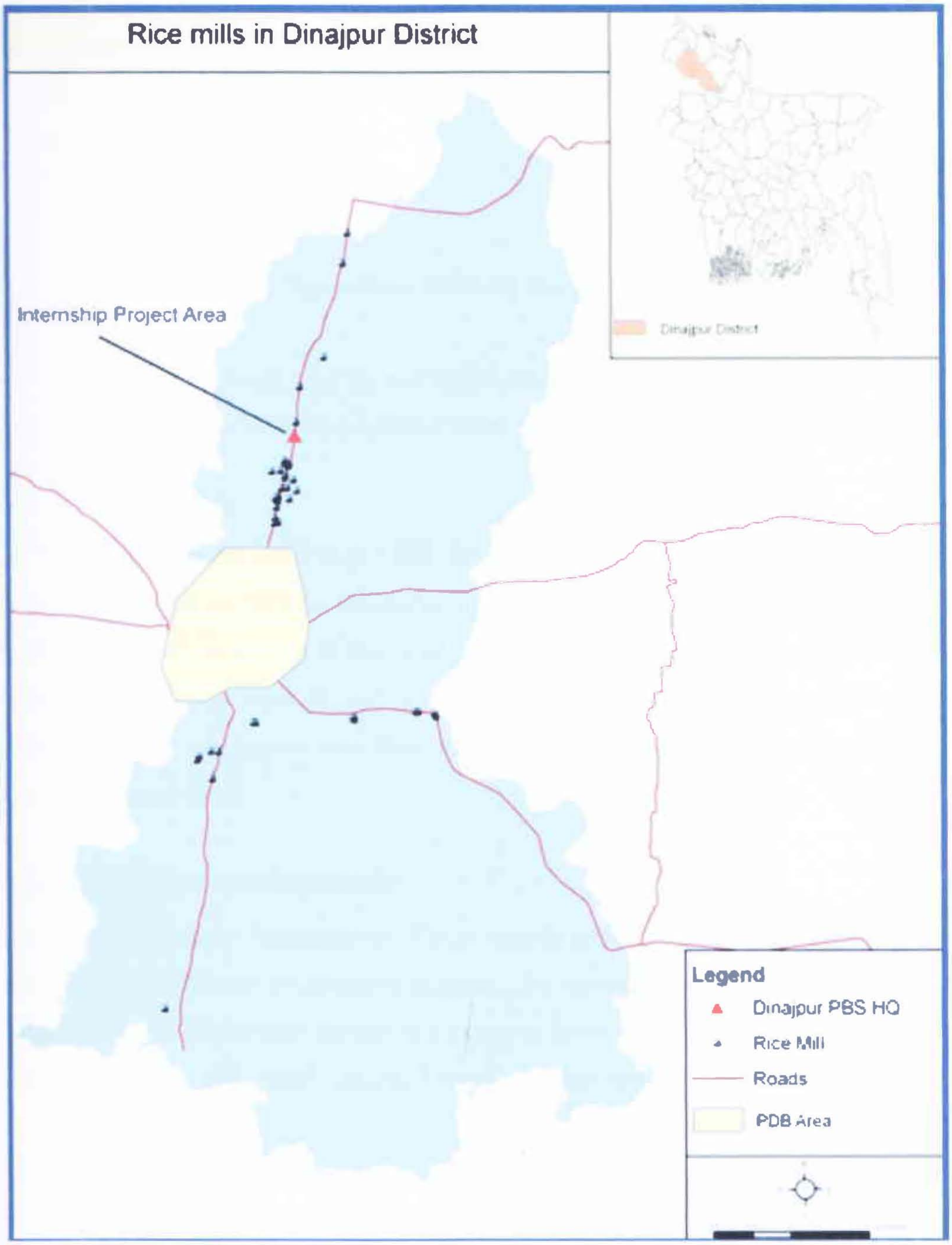


Figure 2-1: Rice Husk concentrated area in Dianjpur

### 2.2.1. Internship Resources

#### i. Hardware

The internship has been done on personal computer. Results of the existing utility model were verified in the field with the help of NRECA International Ltd. using their power measuring instruments.

#### ii. Software

MILSOFT engineering analysis software used for modelling the electric distribution system.

MATLAB software used for writing M-file to analyse the stability of the distribution system. This software is available in the university library for the students of LJMU.

#### iii. Source of data

The first phase of the internship work was to conduct the literature survey. Numerous books, articles and journals on the theory of latest renewable power generation system and its integration with existing grid was used to gain a better understanding of the concepts and previously developed analysis and design methods. The internet is a major source of information with most up-to-date development in power system and work related to rice husk power generation.

### 2.2.2. Limitation of the Internship

This internship mainly depended on official records and REB s reports. The study does not cover critical analysis in an intensive manner. The report partially has been prepared based on the findings within a short period. It s has great limitation. It is expected that the findings of this internship will help various Electric Utility for assess their funding in Rural Electrification project.

Given the time constraints, the reliance has been mainly on secondary materials like REB MIS report, field survey data that are collected different times by individual consultant under supervision of NRECA, published and unpublished including web-based resources. A second source had been interviews of several knowledgeable people.

## 2.3 Power Generation from Rice Husk in Bangladesh

### 2.3.1. Basics of the Biomass Power Generation

Rice husk generated as a by-product of rice processing is an important energy resource. Bangladesh has vast potential to utilize Biomass for power generation, due to an abundant local supply of raw materials such as rice husks, and Bagasee. Rice husk Biomass, in particular, has become an increasingly attractive method of generating electricity in Asia.

The benefits of using rice husk technology are numerous. Primarily, it provides electricity and serves as a way to dispose of agricultural waste. In addition, steam, a byproduct of power generation, can be used for paddy drying applications, thereby increasing local incomes and reducing the need to import fossil fuels. Rice husk ash, the byproduct of rice husk power plants, can be used in the cement and steel industries further decreasing the need to import these materials. In terms of local economic development, renewable energy activities in Bangladesh are expected to create new job opportunities. The Schematic diagram of a Biomass plant is shown in Fig. 2.2.

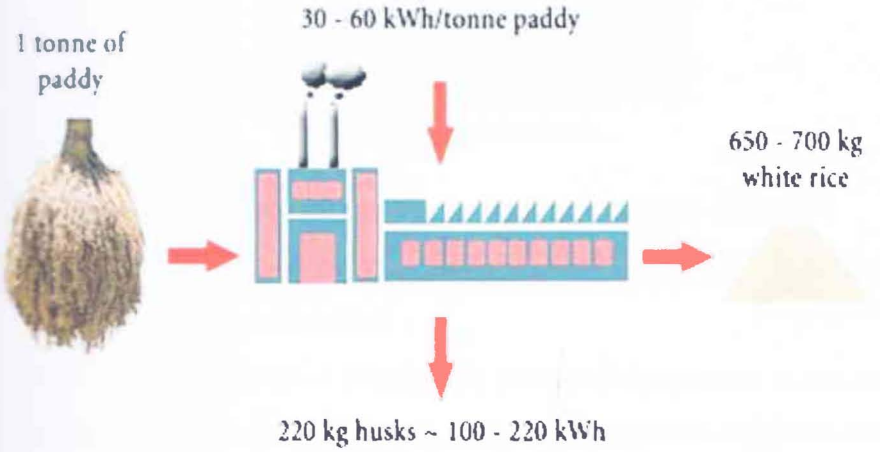


Figure 2.2: Schematic diagrams of a biomass generation stages (a).

rice transplantation rice field

paddy rice husk

modern power plant

Figure 2.2: Schematic diagrams of a biomass generation stages (b).

### 2.3.2. Resource Assessment

Rice is the main crop of Bangladesh, produced everywhere in the country. Rice is double-cropped in many areas and even tripled-cropped where irrigation and soil fertility permit. National rice production in 2006-2007 was 27,319,000 tonnes and has been growing at an annual average rate of 3.8% during the last 10 years. Table 2.1 shows rice and husk production in the top five and the top ten producing districts. This reveals that the five top producing districts produce over 20% of total rice production in Bangladesh, while the next five districts add only 15% to the national production total.

**Table 2.1: Rice Husk production by district (Biomass Report by NRECA, 2009)**

2008 Rice and Husk Production by District

| District | Rank | Rice Production-Tonne | Produced Husk (Ton) | Proportion % |
|---|---|---|---|---|
| Mymensingh | 1 | 1,694,696 | 338,939 | |
| Naogaon | 2 | 1,450,469 | 290,094 | |
| Bogra | 3 | 1,342,331 | 268,466 | |
| Dinajpur | 4 | 1,232,965 | 246,593 | |
| Comilla | 5 | 1,167,202 | 233,440 | |
| Subtotal Top Five | | 6,887,663 | 1,377,533 | 20% |
| Jessore | 6 | 1,099,810 | 219,962 | |
| Netrakona | 7 | 977,455 | 195,491 | |
| Tangail | 8 | 946,520 | 189,304 | |
| Rangpur | 9 | 940,678 | 188,136 | |
| Chittagong | 10 | 840,765 | 168,153 | |
| Subtotal Top Ten | | 11,692,891 | 2,338,578 | 34% |
| National Total | | 34,614,090 | 6,922,818 | |

Rice, rice husk, and rice polish are three milling products. Rice yields typically are in the range of 75-80%, rice polish 1-2%, and the remaining 18-24% is rice husk. Rice husk is a fine and light particle with an energy content of 12,500kJ/kg (5,386 BTU/lb) with an equilibrium moisture content of approximately 8-11%. It can be used for energy applications, and is a suitable input for cement production due to its high silica content. Other current non-energy applications of husk include poultry litter, kitty litter, and poultry and fish feed (both industrial and household). Energy applications of rice husk include production of briquettes for domestic cooking, and industrial boiler fuel for rice parboiling. Fig. 2.4 illustrates some typical rice and rice husk applications in Bangladesh.

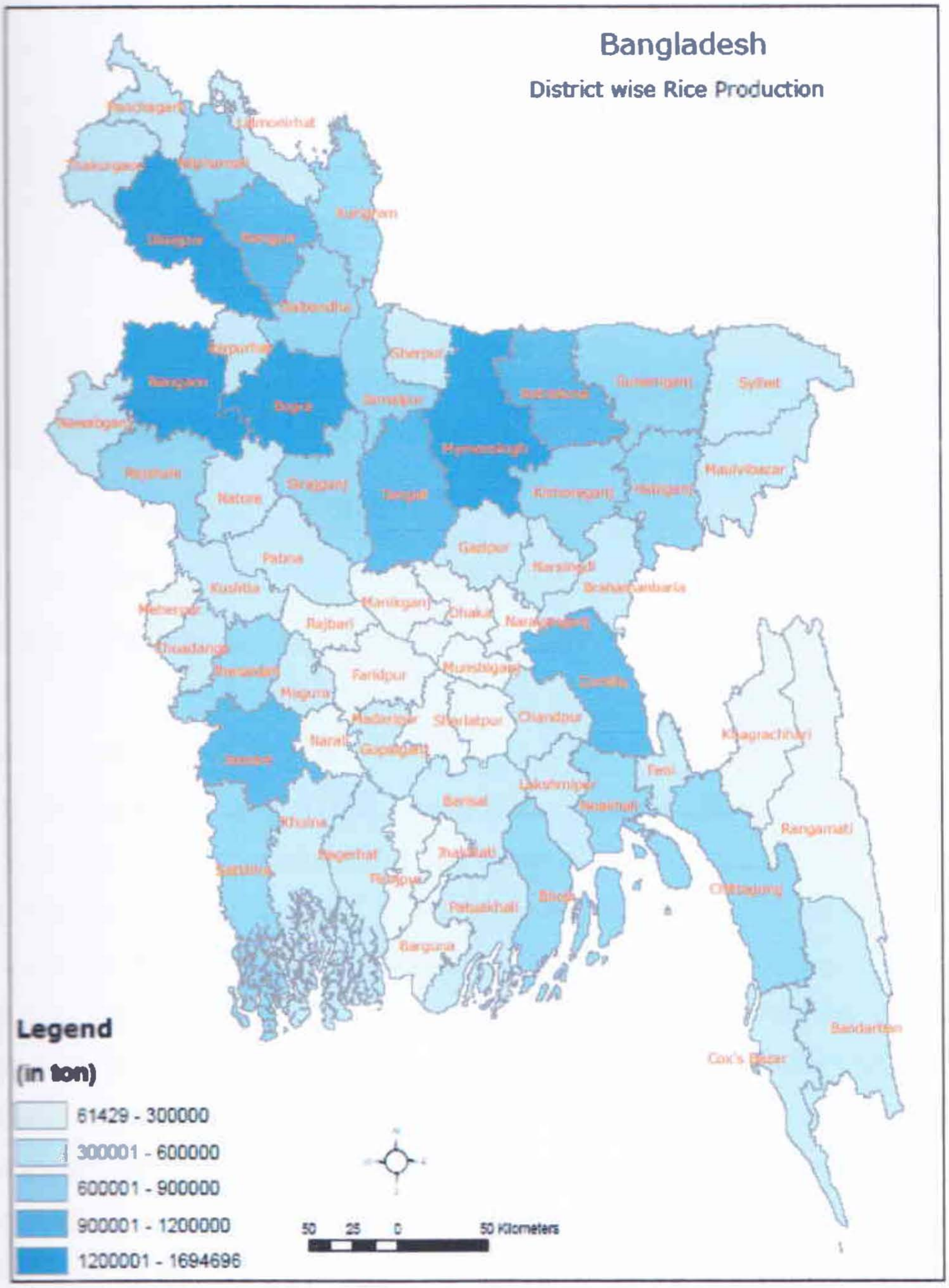
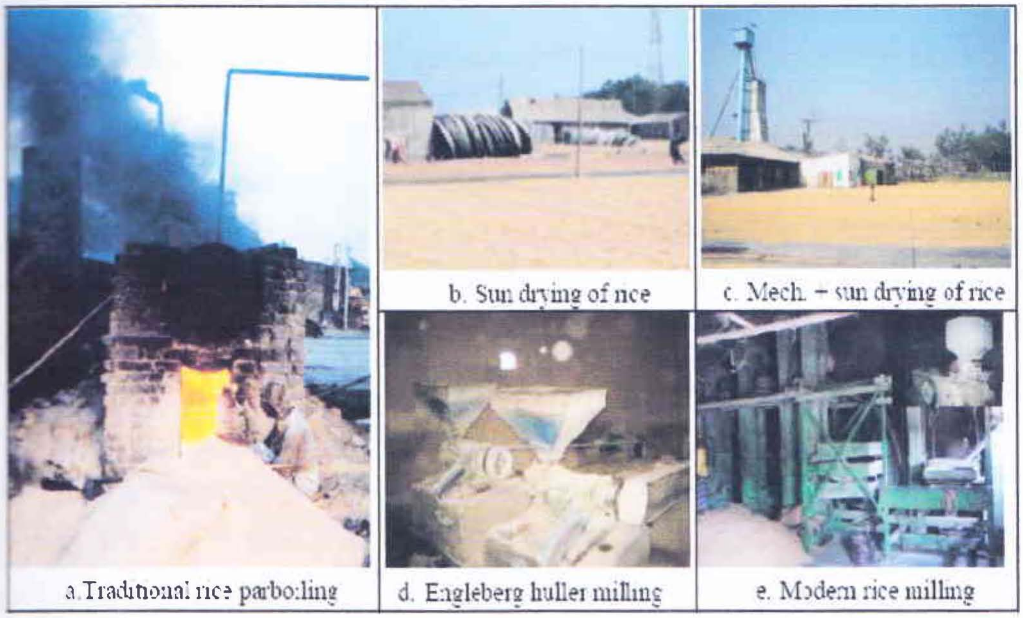


**Figure** 2.3: Shows the geographic distribution of rice production. While rice production is widespread across Bangladesh, it is clear that high levels of production are concentrated in a few districts (nreca biomass report, 2009).



a. Traditional rice parboiling

b. Sun drying of rice

c. Mech. – sun drying of rice

d. Engleberg huller milling

e. Modern rice milling

Figure 2.4: Rice processing operations in Bangladesh (Energies ISSN 1996-1073).

### 2.3.3. Power Generation Potential

A 5 MW plant operating at 23% overall thermodynamic efficiency and a plant factor of 75% would require approximately 3,500 tonnes of rice husk per month. Average milling capacity for the mills included in the study is 20-25 tonnes of rice per mill per day. Assuming a proportion of husk/rice of 20% a typical rice mill produces 4-5 tonnes of husk per day, or 80-100 tonnes of husk per month. Assuming that 50% of the husk still goes to parboiling, it would be necessary to identify between 80-100 rice mills with a total husking capacity of around 2,000 tonnes per day within a 10km radius for each 5 MW rice husk to electricity conversion plant in order to provide sufficient fuel at a reasonable cost. There are a total of 104 rice mills within 5 km of Dinajpur town. Rice mills in this area operate only 6 months out of the year. Husk is available at prices ranging from 2.3Tk/kg during the off season down to 3Tk/kg during peak husking season.

## 2.4 Requirements for Connection of Distributed Generation to Grid

Electric power systems include power plants, transmission and distribution networks connecting the production and consumption sites, and consumers of electric energy. The basic aim of a power system is to deliver the electric power to the customers, fulfilling the power quality demands. It is assured that these demands are met in an economic manner and that the reliability is maintained. Power system experiences a continuous change in demand and the challenge is to maintain at all times a balance between production and consumption of electric energy. Generally a power system is quite large with thousands of buses and transmission lines. The power system is subjected to variety of severe conditions ranging from the faults (may be due to lightning or insulation failures) to the sudden changes in the load conditions. The ability of a power system or a part of a power system to maintain the voltages under normal conditions as well as during a disturbance is called power system stability. This chapter provides a basic introduction to the relevant engineering issues related to the integration of distributed power into power systems.

### 2.4.1. Basic Power System Engineering

Analysis of power system operation in normal and faulty conditions requires appropriate mathematical representation of power system components [Levi]. In this section, the flow of energy in an ac circuit is investigated. By using mathematics, the instantaneous power $p(t)$ is solved into two components (Saadat, 2004). In a power system, there are voltages and currents. Fig. 2.5 shows a single-phase sinusoidal voltage supplying a load.

An alternating current (ac) system can be represented as:

$$v(t) = V_m cos\ (\omega t + \theta_v) \tag{2.1}$$

$$i(t) = I_m cos\ (\omega t + \theta_i) \tag{2.2}$$

$$\omega = 2\pi f \tag{2.3}$$

Where ,

$v(t)$ = Voltage as a function of time

$V_m$ = maximum voltage amplitude

$f$ = frequency, normally 50 or 60 Hz

$i(t)$ =current as a function of time

$I_m$ = maximum current amplitude

$\theta$ = phase shift between voltage and current

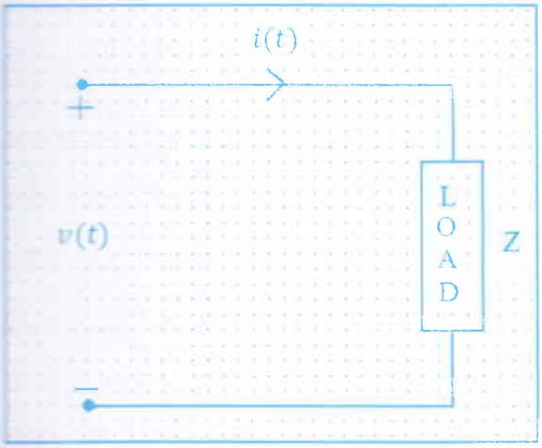


Figure 2.5: Sinusoidal source supplying a load.

The instantaneous power $p(t)$ delivered to the load is the product of voltage $v(t)$ and current $i(t)$ given by

$$P(t) = v(t)i(t) = V_m I_m cos(\omega t + \theta_v) cos\,(\omega t + \theta_i) \tag{2.4}$$

From trigonometric identity

$$cosA\ cosB = \frac{1}{2}\cos(A - B) + \frac{1}{2}\cos(A + B) \tag{2.5}$$

which results in (2.4)

$$P(t) = \frac{1}{2} V_m I_m [cos(\theta_v - \theta_i) + cos2(\omega t + \theta_v) cos(\theta_v - \theta_i) \\ + sin2(\omega t + \theta_v)\, sin(\theta_v - \theta_i)] \tag{2.6}$$

The *root-mean-square* (rms) value of $v(t)$ is $|V| = V_m/\sqrt{2}$ and the rms value of $i(t)$ is $|I| = I_m/\sqrt{2}$ . Let $\theta = (\theta_v - \theta_i)$. The equation (2.6), in terms of the rms values reduced to

$$P(t) = \underbrace{|V||I|\ cos\theta[1 + cos2(\omega t + \theta_v)]}_{\substack{PR(t) \\ \text{Energy flow into the circuit}}} + \underbrace{|V||I|\ sin\theta\ sin\,2(\omega t + \theta_v)}_{\substack{PX(t) \\ \text{Energy borrowed and} \\ \text{returned by the circuit}}} \tag{2.7}$$

where $\theta$ is the angle between voltage and current, or the impedance angle. $\theta$ is positive if the load is inductive, (i.e., current is lagging the voltage) and $\theta$ is negative if the load is capacitive ( i.e., current is leading the voltage).

The instantaneous power $p(t)$ has been decomposed into two components. The first component of (2.7) is

$$PR(t) = |V||I|\ cos\theta + |V||I| cos\theta\ cos2(\omega t + \theta_v) \qquad (2.8)$$

Since the average value of this sinusoidal function is zero, the average power delivered to the load is given by

$$P = |V||I|\ cos\theta \qquad (2.9)$$

This is the power absorbed by the resistive component of the load and is also referred to as the active power or real power. $Cos\theta$ is called power factor. When the current lags the voltage, the power factor is considered lagging. When the current leads the voltage, the power factor is considered leading. The product of the rms voltage value and current value $|V||I|$ is called the apparent power and is measured in units of volt ampere.

$$S = |V||I| \qquad (2.10)$$

The second component of (2.7)

$$PX(t) = |V||I|\ sin\theta\ si\,n\,2(\omega t + \theta_v) \qquad (2.11)$$

The second term in (2.11) pulsates with twice the frequency and has average value zero. The amplitude of this pulsating power is called *reactive power* and is designated by $Q$.

$$Q = |V||I|\ sin\theta \qquad (2.12)$$

For an inductive load, current is lagging the voltage, $\theta = (\theta_v - \theta_i) > 0$ and $Q$ is positive; whereas, for a capacitive load, current is leading the voltage, $\theta = (\theta_v - \theta_i) < 0$ and $Q$ is negative.

MATLAB is used to plot the instantaneous power $P(t)$ and its two components, voltage $v(t)$, and current $i(t)$ as an example. Results are shown in Fig. 2.6 and Fig. 2.7. Fig. 2.6 shows the instantaneous power $P(t)$, voltage $v(t)$, and current $i(t)$. Fig. 2.3 shows the instantaneous power $P(t)$ and its two components.

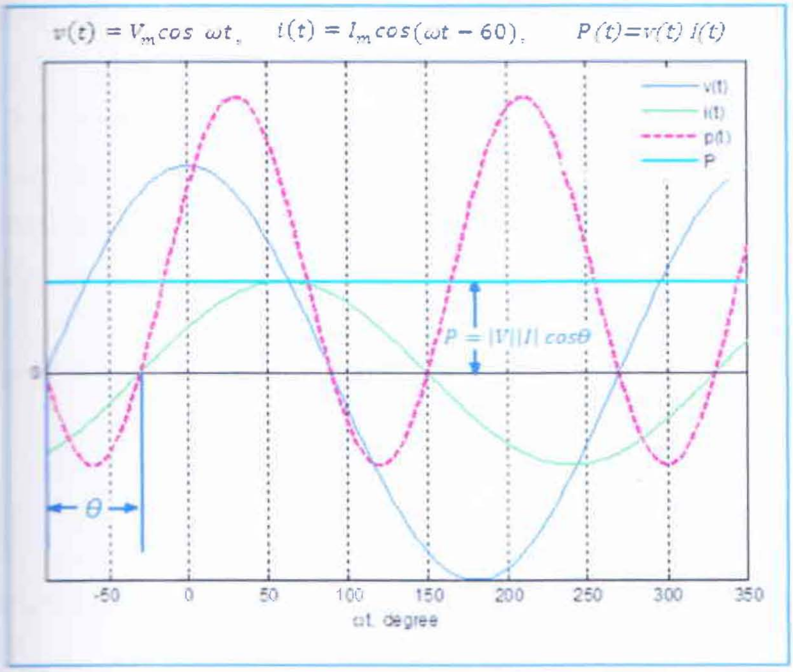


Figure 2.6: Instantaneous power $P(t)$, voltage$v(t)$, and current $i(t)$.

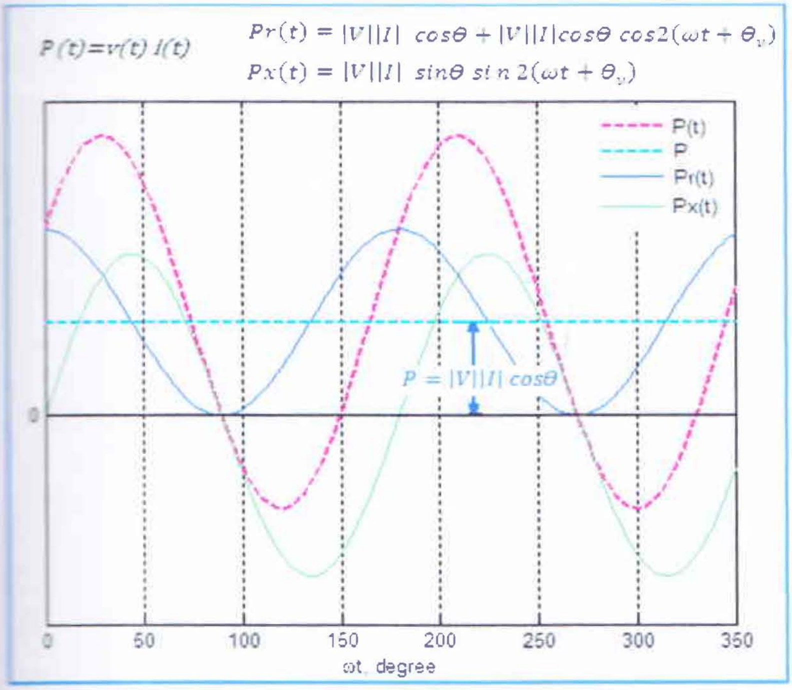


Figure: 2.7. Instantaneous power $P(t)$ and its components.

### 2.4.2 Basic Integration Issues Related to Distributed Power

In most power systems, the power is transmitted using three phases. Loads, transmission lines and transformers can be represented with impedances$Z$, when analysing power systems. This is illustrated in Fig. 2.8.

With voltages (rms values of line-to-line voltages) on each side of the impedance (which may represents a transmission line, for instance), and the current (rms value of the phase current), the voltage drop over the impedance can be calculated as:

$$V_1 - V_2 = \sqrt{3}IZ \qquad (2.13)$$

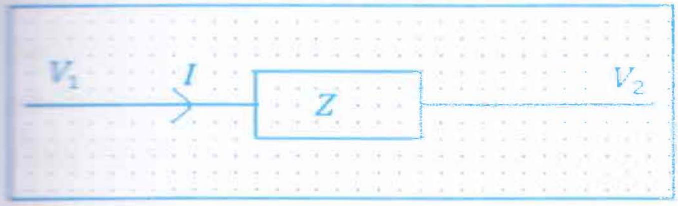


Figure 2.8: Voltages $V_1$ *and* $V_2$ either side of an impedance $Z$ with current $I$

Fig. 2.9 shows a simple arrangement with a husk plant s generator connected to a bus, which is connected to the grid through impedance $Z$. The load which is attached at bus 2 is $P_{Load} + jQ_{Load}$ and the husk power generator is injecting both the active and the reactive power. $P_{Husk} + jQ_{Husk}$ to bus 2. The voltage at bus 1 is denoted by $V_1$ and the voltage at bus 2 is denoted by $V_2$.

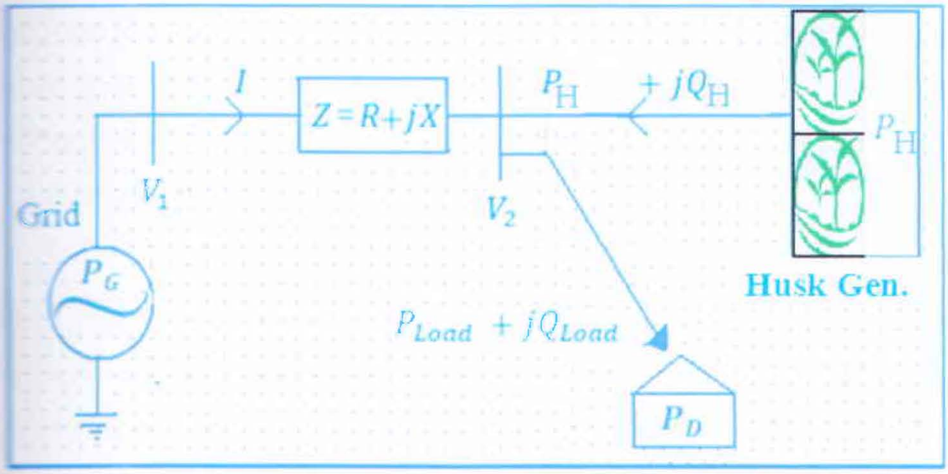


Figure: 2.9. Simple arrangement with a husk farm electricity generation and grid, describing the effect of fluctuating power on voltage.

The model of the power system shown in Fig. 2.10, there are households and industries that consume power $P_D$ and a power station (rice husk) that delivers power $P_H$ . The additional power $P_G$ is produced at another location. In the electric power system shown Fig. 2.11, power cannot disappear. This means that there will always be a balance in this system, as

$$P_G = P_D + P_L - P_H \qquad (2.14)$$

where

$P_G$ additional required power source

$P_D$ power consumption

$P_L$ electrical losses in the impedances $Z$

$P_H$ power production from husk

Equation (2.14) implies that electricity cannot be stored within an electric power system. Hence to secure stable power system operation any change in electricity demand (or power generated from rice husk) must be simultaneously balanced by other generation sources within the power system. Changes in power supply or demand can lead to a temporary imbalance in the system and thereby affect operating conditions of power plants as well as consumers. The requirements for active power control are thus stated in order to ensure stable frequency in the system prevent overloading of transmission lines, insure that power quality standard are fulfilled, avoid large voltage steps and inrush currents at start-up and shut down (Ackermann, 2005).

### i. Reactive Power Control

In a power system the load is mostly inductive and it leads to the consumption of reactive power. These loads are connected to the generation sources by the transmission and distribution lines and the transformers. These components possess considerable inductive reactance and some resistance. It is often undesirable to transport all reactive power demand through these components mainly due to two reasons:

- due to increased power losses
- due to high voltage regulation

### ii. Voltage Regulation

Voltage regulation describes the process and equipment used by an area utility electric power systems operator to maintain approximately constant voltage to users despite normal variations in voltage caused by changing loads (Farret & Simoes, 2006). Voltage regulation and voltage stability are important factors that affect the operation of a power distribution system. From the consumers perspective, the voltage level at the connection point has to stay within an acceptable range, as most of their appliances (e.g. lighting equipment, motors, computers, etc.) require a specific voltage range (e.g. 230V ±10 %) for reliable operation (Ackermann, 2005). Similar to consumer appliances, distributed generation farms require a certain voltage level at the connection point as distributed generator are usually designed to operate within a specific voltage range . If the system is not well regulated or stable, the generators that receives power from this system will not operate efficiently. This can be understood from an example given as follows:

Applying $KVL$ on circuit shown in Fig. 2.8:

$$V_1 = V_2 + \sqrt{3}IZ \tag{2.15}$$

When the power production from a induction machine is enough to meet the load demand, there will be no current drawn from the grid i.e. $I = 0$. Applying current $I$ equal to zero.

$$V_1 = V_2 \tag{2.16}$$

When the power production from the distributed generation plant is more than what is demanded by the load or the load has decreased due to any reason then the voltage at bus 2 will be greater than the voltage at bus1.

$$V_1 < V_2 \tag{2.17}$$

When the power production from the induction machine is low, then the difference between the power generated by the induction machine and the load will be supplied by the grid. The current drawn from the grid, will pass through the impedance $Z$ and the resulting voltage at bus 2 i.e. $V_2$ will be less than the voltage $V_1$.

$$V_1 > V_2 \tag{2.18}$$

The voltage level in the transmission system is kept at a technical and economical optimum by adjusting the reactive power supplied or consumed. Power plants and special equipment, (e.g. capacitors and reactors) control the reactive power. The voltage ratio of different voltage levels can be adjusted by tap-changers in power transformers. This requires a reactive power flow between different voltage levels. In order to manage the voltage level during disturbances, reactive reserves in power plants are allocated to the system. These reserves are used mainly as primary reserves in order to guarantee that the voltage level of the power system remains stable during disturbances (Ackermann, 2005).

### Frequency Control

Frequency in the power system is an indicator of the balance between production and consumption. For the normal power system operation the frequency should be stable and close to its rated value. In Bangladesh the frequency is usually between 50±0.1 Hz and falls out of 49-50.3 Hz range very seldom. In Bangladesh frequency relays are used in grid substation to control the frequency.

### Flicker

One aim of the power system is to provide the power according to customer demand when it is needed but also in a form (i.e. waveform and frequency), which is either equal or close to the specified standard. This requirement is often referred as  Power Quality . Power quality is related to factors that describe the variability of voltage levels as well as distortion of voltage and current waveforms (Larsson & Santjer, 1999). The power fluctuations from distributed generation plant during continuous operation cause corresponding voltage fluctuations on the grid.

Flicker can be described as a power quality concern regarding the unsteadiness in *rms* value of voltage. Voltage variations and harmonics can damage and shorten the lifetime of the utility and customer equipment. Voltage flicker causes visible variations of the light intensity in bulb lamps. Inrush current may cause tripping of the equipment by its protection (Ackermann, 2005). On the other hand power quality problems cause more concern in the distribution networks due to the direct impact on customers. Therefore more attention is paid to power quality aspects in the recommendations for connection of distributed generation plant to medium and low voltage levels.

The section has included basic electric power system theory and the basics of how distributed generation power integration behaves in order to arrive at a better understanding of integration issues. The overall aim of power system operation, independent of distributed generation power penetration levels, is to supply an adequate voltage to consumers and continuously to balance production and consumption. Furthermore, the power system should have an acceptable reliability level, independent of distributed generated power penetration.

## 2.5 Power System Modeling and Analysis Case Study Area

In this section power flow analyses is carried out to determine the adequacy of the sub-transmission networks supplying power to Dinajpur PBS-1 33 kV network, and to demonstrate the impact of distributed power (from rice husk) integration on the network. The analysis undertaken for this report included collection of a geographic information system (GIS) map and detailed consumer information for the feeder, collection of measured loading data, and preparation of a power flow analysis.

### 2.5.1 Service Area, Distribution System, and Power Supply

Dinajpur PBS-1 serves an area encompassing over 1,600 square kilometres of semi-urban and rural area in northwest part of Bangladesh. Power is provided to the PBS through two locations: the grid 132 kV substation which transforms power to 33 kV. PBS 33 kV transmission line deliver power from this source to five (5) existing distribution voltage substations that transform the power to 11 kV for distribution. Twenty-five (25) existing feeders radiate from these substations to deliver power to over 95,868 (REB MIS August 2010) consumers with demand of 40 MW.

### 2.5.2 Components of Load Flow Analysis

Load flow analyses are necessary to properly dimension electrical characteristics of electric distribution systems. Load flow analyses comprise several components. First, a demand analysis must be performed to estimate initial expected electric consumption and power requirements. Thereafter, the demand growth must be developed to estimate growth in consumers, in specific consumption, and in total energy and power demand over the project life.

#### i. kW Demand

Energy use in the study areas is dominated by residential consumption. Consumption for irrigation energy use is minimal. Approximately 54% of all energy consumed is for residential purposes as shown in Fig. 2.10 Commercial energy use is relatively low considering that Dinajpur is one of the best rice production areas in Bangladesh. Industrial energy use is quite higher, and could increase more once the rice husk farm is interconnected to the distribution network.

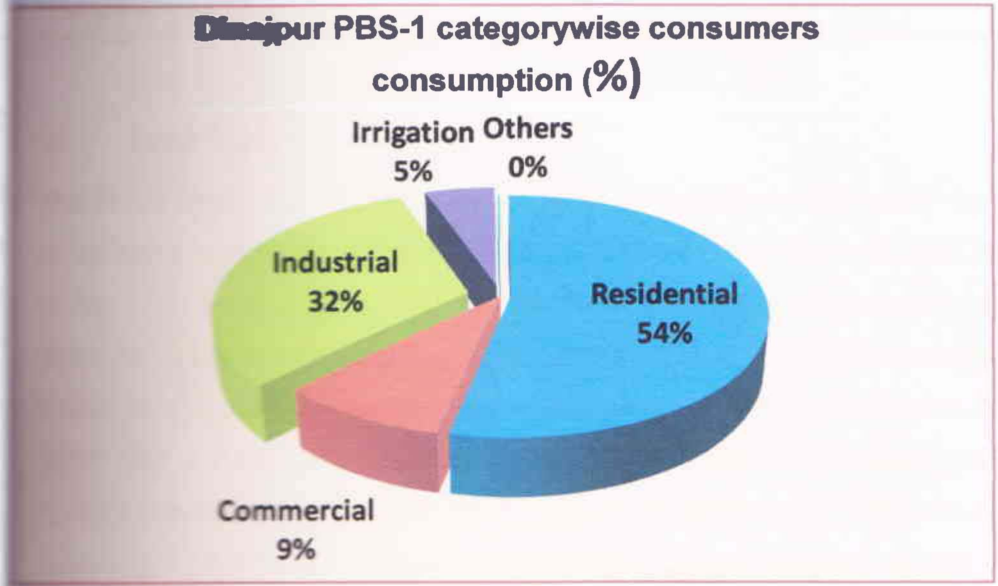


Figure 2.10: Electricity consumption characteristics & consumer mix in Dinajpur PBS-1

In order to determine the demand in kW likely from the group of consumers, the data on consumption was combined into a single average consumption value of 80 kWh/consumer/month. Energy consumption averages for each consumer category, and the ratio of consumers in each category are shown in Table 2.2.

**Table 2.1- Dinajpur PBS-1 kW demand estimates.**

| Consumer Category | Number of Consumers | Billing MWh/Mon | Average Consumption kWh / Mon | % of total Consumption | Average kWh/Consumer |
|---|---|---|---|---|---|
| Residential | 75250 | 4451 | 59.1 | 53% | 32 |
| Commercial | 10977 | 773 | 70.4 | 9% | 7 |
| Industrial | 2407 | 2675 | 1111.3 | 32% | 356 |
| Irrigation | 7078 | 433 | 61.2 | 5% | 3 |
| Others | 145 | 12 | 82.8 | 0.14% | 0.1 |
| Total | 95857 | 8344 | Ps | | 80 |
| Substation Name | Consumer in Phase A | Consumption Phase-A kWh / Month | | kW Load Phase- A | Total kW Load Phase ABC |
| PBS HQ | 7868 | 3128822 | | 4346 | 13037 |
| Sadipur | 6894 | 2741444 | | 3808 | 11423 |
| Birganj | 5688 | 2261691 | | 3141 | 9424 |
| Kaharole | 3942 | 1567391 | | 2177 | 6531 |
| Uthrail | 7561 | 3006649 | | 4176 | 12528 |

Source: Data collected from the MIS report August, 2010 published by Rural Electrification Board Bangladesh.

## 6. Load Curve

The 33 KV feeders for Dianjpur PBS are routinely load-shed almost every day for six hours or more due to shortage of power generation. The daily load curve for April 22 is presented in Fig. 2.11. Examining the figure provides several interesting observations. For one thing, there are typical three dips in load shown on the curve, in spite of the fact that there was no formal load shedding. The dips are occurring at midnight to 6:00 am, at 1:00pm due to lunch time in factories and offices, and at around 5:00 pm due to closing time for offices. Load is increases during the peak hours (7 pm to 10 pm) than it is during the day, and due to extremely high demand the system is vulnerable to load shedding. On the other hand, it confirms that most of the feeder load consists of resistive appliances, such as incandescent lighting. This is not surprising considering most of the consumers are rural under this 33 kV network. Another indicator is that the daily load factor which is the ratio of the average load over a designated period of time to the peak load occurring during that period (American Standard Definitions of Electric Terms, 1957). The load factor is 60%, which is quite high for semi-urban and rural area. While this is a good thing from a utility load characteristic standpoint, it indicates that there will almost certainly be a change in consumption characteristics after the distributed rice husk based electricity nd generation begins and power is available on a more regular basis.

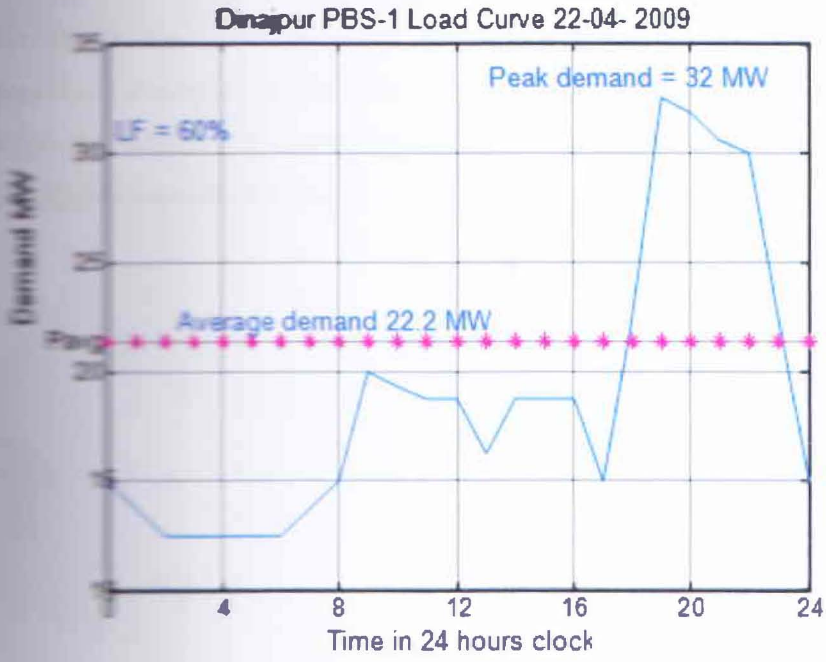


Figure 2.11: Typical daily load curve of Dinajpur PBS-1

### iii. Demand Analysis

The load growth of the geographical area served by a utility company is the most important factor influencing the expansion of the distribution system. Therefore, forecasting of load increases is essential to the planning process. A few decades ago the growth in customers was reasonably steady and the demand per customer continued to increase. However, in recent years the picture has significantly changed. Energy conservation, load management, increasing electric rates, and a slow economy have united to slow the growth rate. As a result, more meticulous methods are required for load forecasting. Least-square exponential technique was used to develop a Matlab program for demand forecasting of Dinajpur PBS-1. This technique is based on regression analysis which is the study of the demand behaviour of a time series or a process in the past and its mathematical modelling so that future demand behaviour can be extrapolated from it (Gonen, 2007).

The principal of regression theory is that any function $y = f(x)$ can be fitted to a set of points $(x_1, y_1)$, $(x_2, y_2)$ so as to minimize the sum of errors squared to each point, that is

$$e^2 = \sum_{i=1}^{n} [y_i - (a + bx_i)]^2 = \text{minimum}. \qquad (2.1)$$

Where $a$ and $b$ are regression coefficients.

Dinajpur PBS-1 load growth rate is 11.5% per annum. The growth curve shown in Fig. 2.12 indicates that load growth increased at a higher rate in the last ten years and will continue to increase in the next five years, because it is assumed that the system will undergo significant expansion in the early years of husk power generation farm implementation. After the system has expanded to serve the economically viable rural communities, consumption growth will slow.

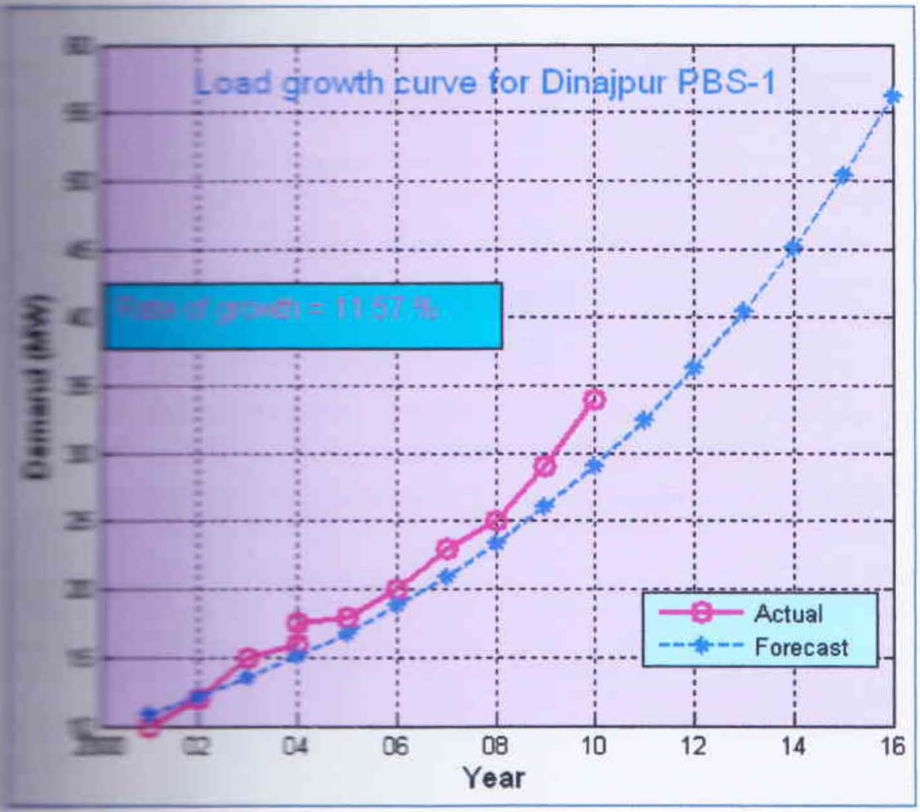


Figure 2.12- Load Growth Curve for Dinajpur PBS-1

**M-File for Demand Forecasting**

```
%Demand forecasting matlab program
%%%%%%%%%%%%%%%%%%%%%%%%%%%%5
fprintf('\nDemand Forecast\n');
fprintf('\nEnter an array of demand values in the form:\n');
fprintf('\n[yr1 ld1; yr2 ld2; yr3 ld3; yr4 ld4; yr5 ld5]\n');
past_dem=input('\nEnter year / demand values:');
sizepd=size(past_dem);

%get the # of past years of data and the # pf cols in the array
np=sizepd(1); cols = sizepd(2);

%get the # of past years to predict
nf=input('\nEnter the number of year to predict:');
ntotal=np+nf;

%obtain the least-square terms to estimate the ld groth value g
%y=a*b^x must be transformed  to ln(y)= ln(a) + x*ln(b)
Y = log(past_dem(:,2))'; X = 0:np-1;
sumxx = (X-mean(X))*(X-mean(X))';
sumxy = (Y-mean(Y))*(X-mean(X))';

% get the coeffs of the transformed data A = ln(b) and B = ln(a)
A=sumxy/sumxx; B = mean(Y)-A*mean(X);
```

```
%Solve for the initial value, Po and g
Po=exp(B);
g=exp(A)-1;

fprintf('\n\tRate of growth = %2.2f %%\n\n', g*100);
fprintf('\tYEAR\tACTUAL\t\tFORECAST\n');

%Calculated the estimated values
est_dem = [];
for i = 1: ntotal
    n=i-1;
    % year = first year + n
    est_dem (i,1) = past_dem(1,1)+ n;
    %Load growth equation
    est_dem (i,2)=Po*(1+g)^n;
    if i<= np
        fprintf('\t%4d\t%6.2f\t\t%6.2f\n', est_dem(i,1), past_dem (i,2),
est_dem (i,2));
    else
        fprintf('\t%4d\t-\t\t\t%6.2f\n', est_dem(i,1), est_dem (i,2));
    end
end
plot(past_dem(:,1), past_dem(:,2), 'm-o', est_dem(:,1), est_dem(:,2),'b--
*','linewidth',1.5);
xlabel('Year'); ylabel('Demand'); legend ( 'Actual','Forecast');
title('Load growth curve for Dinajpur PBS');

hold on
grid on
```

### 2.5.2. Power Flow Modeling

A power flow model of the 33 kV network of Dinajpur PBS-1 was developed by importing the GIS positioning map, plus category wise consumers, conductor size and line configuration information obtained from Dinajpur PBS-1, into an analysis program called WINDMIL. This software is the most commonly used distribution analysis program for many countries rural electric cooperative program. The model prepared simulates the 33 kV lines, transformers and rice husk farms generators. The load data collected from the REB MIS report 2010 was used to allocate the calculated load among the various line segments in proportion to the number of consumers, their class and their average kWh consumption. The 5 MW rice husk generation farm shown in the single line diagram, was simulated by 5*1 MW generation units. A squirrel-cage induction generator (SCIG) is chosen for the farm. The stator winding of these generators is connected directly to the 50 Hz grid. In order to generate power the induction generator speed must be slightly above the synchronous speed. Speed varies approximately between 1 pu at no load and 1.003 pu at full load.

The following criteria and minimum standards were used in Power Flow analysis.

a. The new generation unit supplies power to the feeder rather than directly to the substation. The voltage at the point of common coupling (PCC) should be within acceptable limits, ± 5% (REB, 2008).
b. The maximum voltage drop on primary distribution lines should not exceed 6.9 volts (230 volt base), after re-regulation. This follows design criteria as stated in PBS Instruction Series 100- 21-1-2 (REB, 2008).
c. Primary conductors (transmission or distribution) must not be loaded over 80% of thermal capacity due to safety considerations.

A series of power flows were simulated to assess the steady state operation of the network, with an increasing amount of power from the new husk plant. The considered cases are:

Case A: No Generation- base system without distribution fixes
Case B: No Generation- future case (5 years load growth) without distribution fixes.
Case C: Generation (5*1MW) base system with distribution fixes.

### i. Case A-Simulation Results

The map in Fig. 2.13 illustrates the existing electric distribution system simulation of voltage analysis result. Load allocated at the control point is 45 MW; however present peak demand is more than this (including PDB and PBS substations). The electrical model shows that voltages are inadequate at the far end substations. The voltage drop information after power flow analysis against each substation is shown in Fig. 2.13 Network voltage levels are extremely low. Voltages, even at the farthest substations are between 93% to 94%. This should be compared to the requirement of the design criteria as stated in PBS 100- 21-1-2, which states that minimum sub-transmission system voltage should remain within a range of 95% to 105% per-units under normal operating conditions (REB, 2008). This relates to a range of 218.5 volts to 241.5 volts on a 230 volt base or 31.35 kV to 32.65 kV on a 33 kV base. The red lines indicate low voltage at existing 33 kV lines; the black lines indicate sufficient level of voltage at 33 kV lines. The electrical model also shows that at the main 33 kV 22.5 km long backbone line huge losses occur. The text box next to the 132/33 kV Grid source shows that the system results in 1.5MW, or 3.5%, losses. Summary of the load flow study are shown in Table-2.3 and in greater detail in Appendix C.

**Table 2.3-Summary of the balanced voltage drop report-Case A**

| Load | | Capacitance | Charging | Gen & Motors | Losses | No Load Losses | Total |
|---|---|---|---|---|---|---|---|
| kW | 43361 | 0 | 0 | 0 | 1573 | 27.00 | 44961 |
| kVar | 11386 | 0 | -211 | 0 | 10349 | | 21524 |

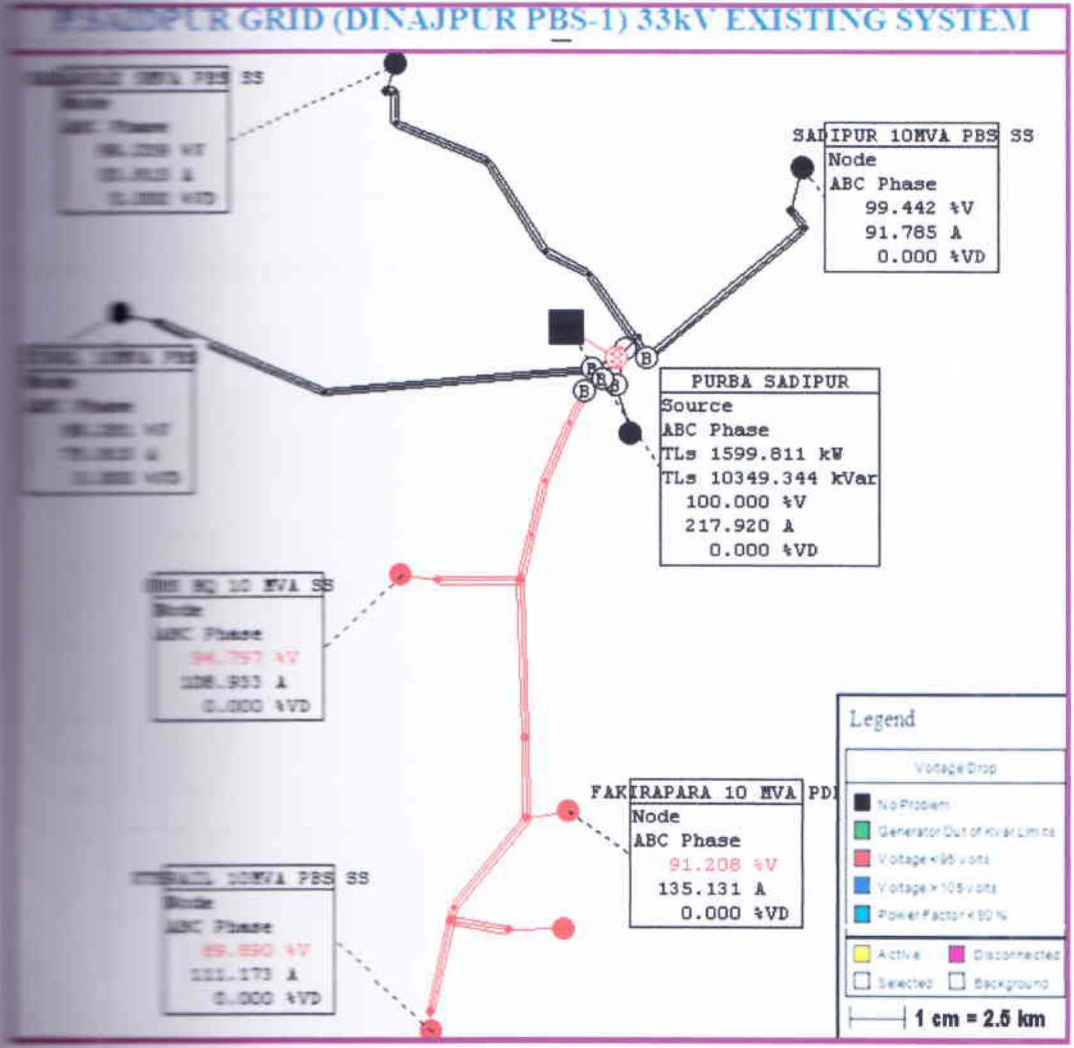


Figure 2.13: Voltage Drop Simulation result for Case A: no generation-base system without distribution lines

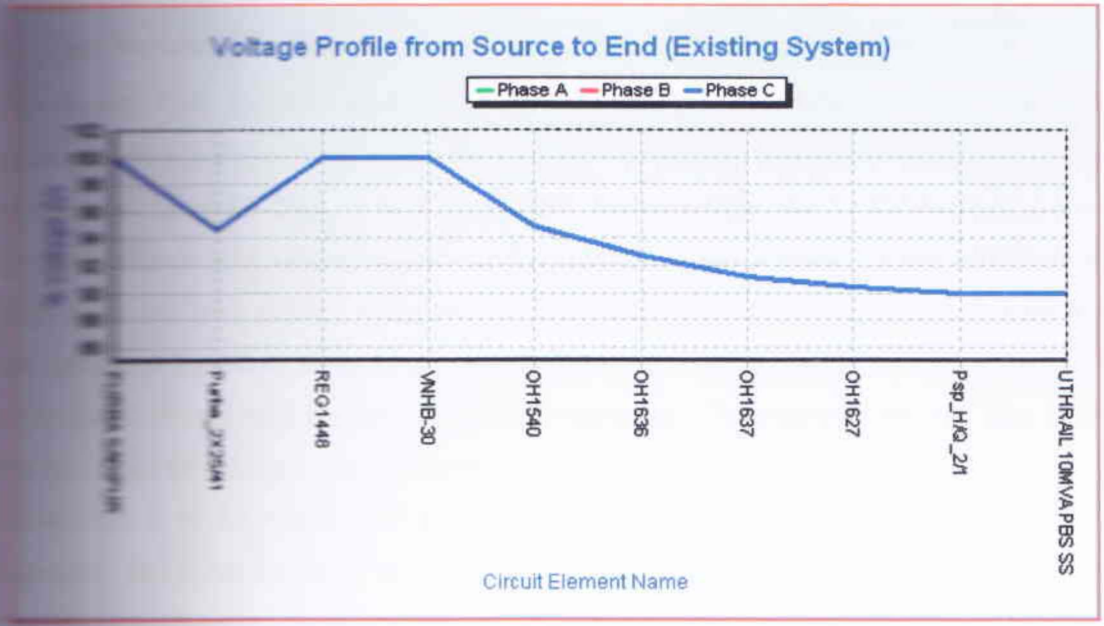


Figure 2.14: Voltage condition from Source to End (Case-A)

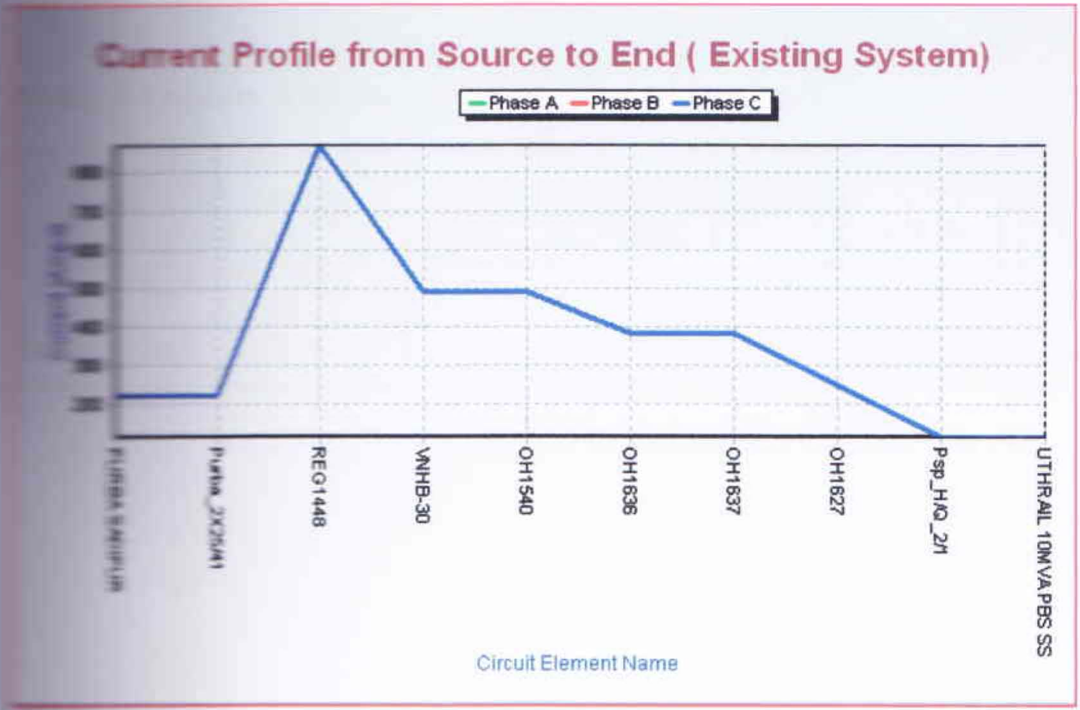


Figure 2.15: Load Flow condition from Source to End (Case-A)

### 6. Case B-Simulation Results

The second load scenario model uses an identical system configuration, but specific consumption was increased to reflect the load growth for next five years. Total load for the system was increased from 45 MW to 59 MW. Unfortunately, the 33 kV network around Dinajpur PBS is very extensive, and serving this load from a single source will result in high losses and poor voltage at the ends of the system. Power flow modelling showed that the voltage performance under projected conditions is very poor, with voltages below 84% with (on a 230 volt base) on many 33 kV line segments. The results of the load flow study for the projected demand case are shown in Fig. 2.16. The electrical model of this system shows that it is not capable of supplying adequate voltage during the next five year operation, due to the length of the 33kV line. The red sections in the diagram indicate that the 33kV line experiences under-voltage (84%). The electrical model also shows that at the main 33 kV 25 km long backbone line huge losses occur. The text box next to the 132/33 kV grid source shows that the system results in 3MW, or 6%, losses. Summary of the load flow study is shown in Table-2.4 and in greater detail in Appendix C.

**Table 2.4-Summary of the balanced voltage drop report-Case B**

| Load | | Adjustment | Charging | Gen & Motors | Losses | No Load Losses | Total |
|---|---|---|---|---|---|---|---|
| kW | 56370 | 0 | 0 | 0 | 2888 | 27.00 | 59282 |
| kVar | 14803 | 0 | -206 | 0 | 19212 | | 33809 |

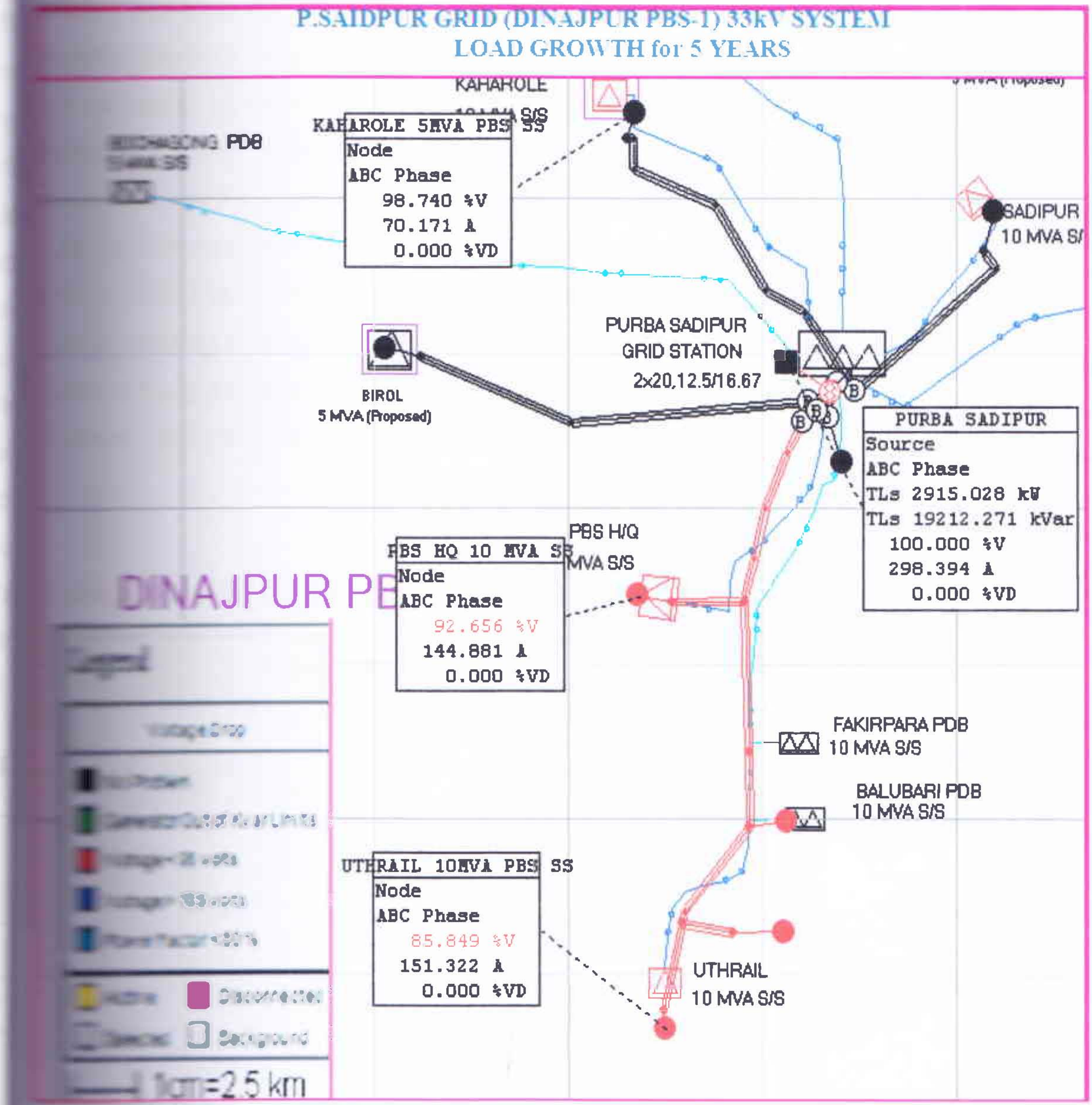


Figure 2.16-Voltage Drop Simulation result for Case B: No Generation- future case (5 years load growth) without distribution fixes.

### iii. Case C-Simulation Results

In this case, the generation from 5 *1 MW generators is considered. The results of the load flow study after husk power plant power integration are shown in Fig. 2.17 Power flow modelling showed that the overall performance of the entire 33 kV network changed significantly. The electrical model of this system shows that it is capable of supplying adequate voltage to the 33 kV Utrail feeder. However, consumers at the ends of the Utrail 11 kV line face voltages of 96% or less. In order to improve the voltage at the ends of the lines, it was necessary to introduce other modification measurers such as the installation of switched capacitor banks and transformer tap adjusting in the substation.

An additional capacitor bank was used in the simulation model as the target voltage criterion is raised towards the 95% (218.5 volts on a 230 volt base) minimum limit contained in the PBS design instruction.

The text box next to the 132/33 kV grid source shows that the system results in 970 kW, or 2.1% losses. This indicates that integration of electricity generated by the husk farm into the existing system not only improves the conditions of voltage but also reduces the losses of the system significantly (losses reduced from 3.5% to 2.1%).

Summary of the load flow study is shown in Table-2.5 and in greater detail in Appendix C.

**Table 2.5-Summary of the balanced voltage drop report-Case C**

| Load | | Capacitance | Charging | Gen & Motors | Losses | No Load Losses | Total |
|---|---|---|---|---|---|---|---|
| kW | 43361 | 0 | 0 | -5000 | 915 | 52.00 | 39338 |
| kVar | 11386 | -4458 | -220 | -2421 | 6664 | | 10950 |

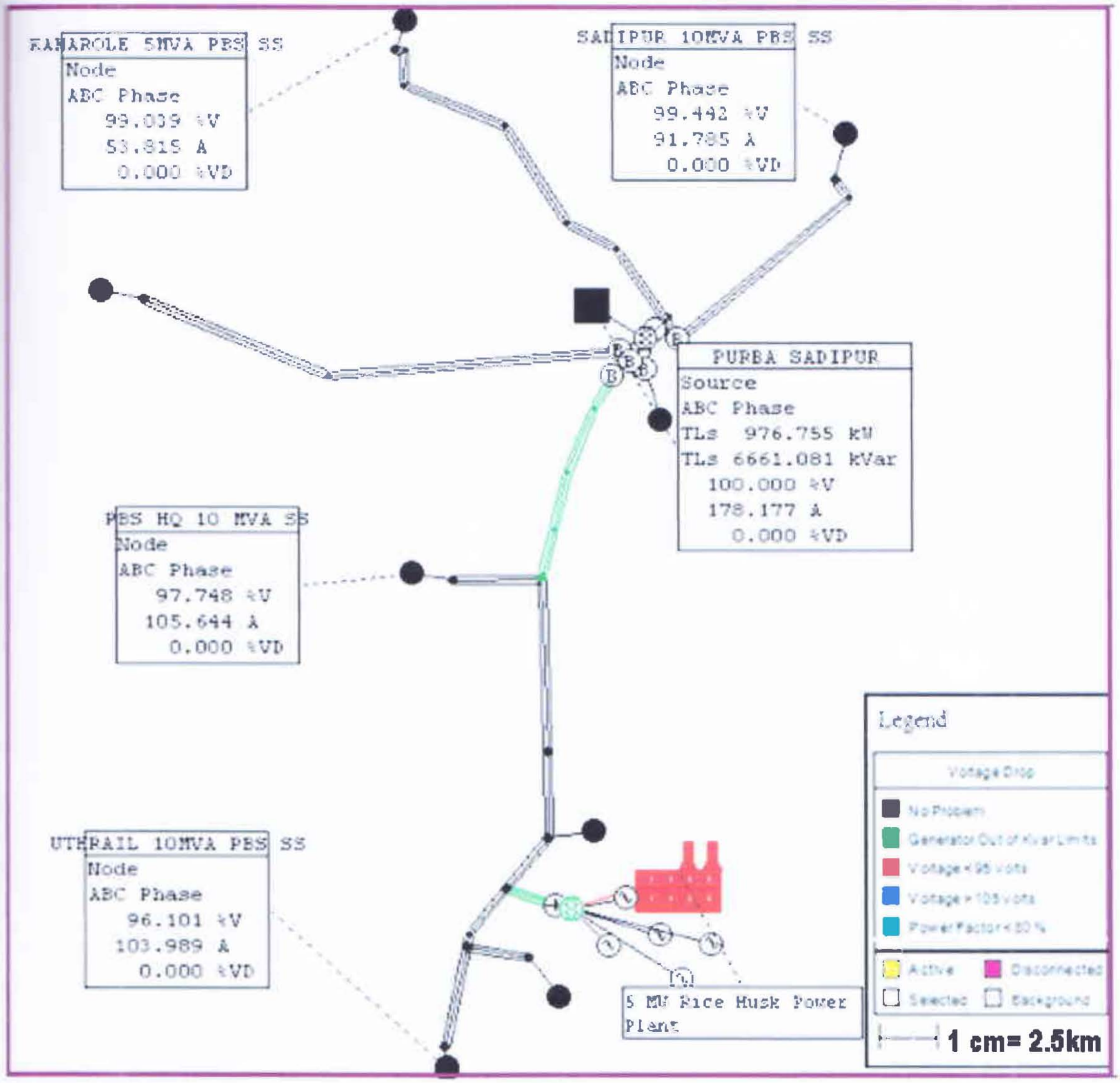


Figure 2.17-Voltage Drop Simulation result for Case C: generation (5*1MW) Base system with distribution fixes.

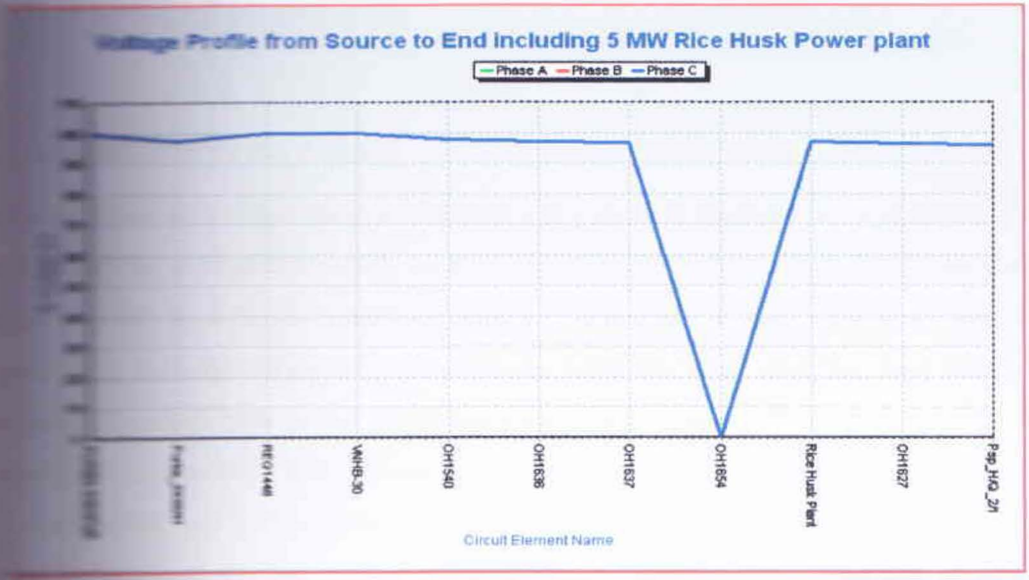


*Figure 2.18: Voltage condition from Source to End including Husk Farm (Case-C)*

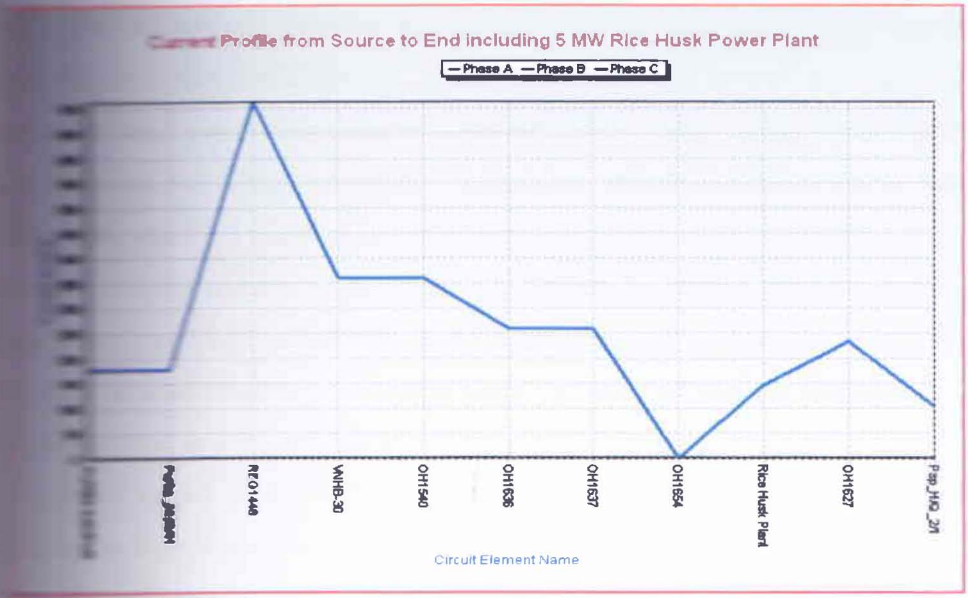


Figure 2.19: Load condition from Source to End including Husk Farm (Case-C)

Fig. 2.18 shows the voltages from the new generation plant to grid source. As the power injection from new plant reaches 5 MW, the voltage at line segment OH1627 increases significantly, followed by an increase in the load voltages. The active power flow from the grid to the load falls to zero at grid as shown in Fig. 2.19. The voltages at the terminals of husk plant increase to approximately 96%.

# Chapter 3: Problems and Recommendations

## 3.1 Availability of Rice Husk

The main obstacles to Husk generated power integration in Bangladesh originate from the rice husk are the availability/ supply of husk because production of rice totally depends of annual rain fall as a result cannot be forecast accurately. Power generated from husk injected into the grid varies unpredictably on both the short and the long term. The intermittent nature of husk power generation plant makes power system operation especially challenging. An important factor in considering rice husk as a potential biomass fuel is that much of the rice sold in Bangladesh is parboiled at the mill. Parboiling is a process that alters the flavour of the rice and improves its storage characteristics, and it is carried out using steam produced in rice husk fired boilers. As the value of husk has traditionally been low, there has never been any significant incentive to use the rice husk fuel efficiently. With a few exceptions, most of the boilers used in rice mills today are informally constructed and quite inefficient (i.e., about 20% efficiency), as well as unsafe. Most husks generated in large automatic rice mills is entirely consumed as the source of thermal energy needed both for parboiling and drying. Preliminary estimates indicate that at least 50% of the rice husk consumed could be saved by employing more efficient boilers.

Conversion from traditional, lower pressure boilers to higher pressure, high efficiency boilers would require an investment on the part of the mill owners, and their willingness to make such an investment would depend upon the value of such an investment. Either the price of rice husk as a by-product would have to increase, or the electricity generated from the increased output of the boilers would have to provide a sufficient return to trigger investment in improved energy conversion technology.

Husk that is not used for parboiling is sold as a byproduct for multiple purposes, including poultry bedding and briquetting as a cooking fuel. The price of rice husk varies from district to district. In some districts it is a costly item where it is the main fuel for household cooking. In Kushtia district it costs 6 Tk/kg. In the North Western region it varies from 2 to 3 Tk/kg. The remaining mix of ground rice husk and bran from Engleberg huller mills is currently sold out for feed at 3.54 Tk/kg, compared to rice husk from large automatic rice mills sold to briquette industries at about 2.78 Tk/kg (GTZ, 2008).

## 3.2 Rice Husk Power Generation Generator Technology

The conversion of energy from rice husk into electrical energy is not a simple process. The design and optimization of the plant require knowledge of technology; that of the knowledge of mechanical process and generation engineering, and that of the controllers and the protection system knowledge of electrical engineering and control systems. Rapid and flexible control of other generators is required to balance power generation with demand (Georgilakis, 2006).

A number of methods for production of power from rice husk have been made, but most are based on the use of producer gas technology that generates fuel gas capable of being used in a modified reciprocating engine-generator. Biomass gasification systems, when deployed with internal combustion engines are generally designed to use diesel fuel to supplement the producer gas due to the relatively low heating value of the producer gas.

The relatively high cost of electricity production, coupled with the relatively small capacity of biomass gasification plants (they are available up to approximately 600kW) makes use of biomass gasification problematic. A 5MW biomass combustion plant is of sufficient scale to allow use of more energy efficient technology such as regenerative feed water heating, with the result that an overall plant efficiency of 22-25% is achievable. Concentration of the power production capacity also reduces operations and maintenance cost on a per unit basis, and makes the investment more attractive.

## 3.3 Grid Connection of Distributed Power Generation

Electricity cannot be stored in large quantities. Whilst stand alone husk-diesel or husk-battery systems do exist, the majority of large husk power generation plant are erected in countries with an extended electricity grid and these are hence connected to this grid for example in India and Thailand. The voltage at the generator s terminals is normally lower than the voltage of the grid to which it is connected, leading to the need for a transformer. Further, switchgear is necessary to disconnect the generator in case of a short circuit or preventive maintenance.

In distributed risk husk plant electricity, generating systems are different from the conventional directly grid coupled synchronous generator which is traditionally used in power plants are applied. Due to their different characteristics, these generating systems interact differently with the power system than synchronous generators. This means that they respond to disturbances, such as changes in terminal voltage and frequency or prime mover power, in a different way and that their capability to contribute to grid voltage control may be less (Ackermann, 2005). Distributed energy generation equipment is most often installed in remote, rural areas. These remote areas usually have weak grids, often with voltage unbalances and under voltage conditions. Also an induction generator connected to an unbalanced grid will draw unbalanced current. These unbalanced current tend to magnify the grid voltage unbalance and cause over current problems as well.

In power systems, the power utility companies are bound to deliver power to the consumers within acceptable voltage limits and good power quality. The issues like steady state voltage changes and power quality have to be addressed before a connection of distributed generation is allowed so that it can be assured that connection of a certain amount of distributed power to the grid is not going to deteriorate the network conditions.

# Chapter 4: Conclusion

Rice husk power generation is one of the most environmental friendly and cost-effective resources among different renewable energy technologies. In this internship investigations are carried to find how much husk generation power that can be integrated into an existing distribution grid. Steady state voltage changes, thermal limits of lines and transformers are considered as the limiting factors during these investigations. For these investigations, the distribution grid is modelled in the power system simulation software Windmil. The modelling is done on the basis of information collected from the relevant distribution company. These investigations are done for different load conditions.

This internship report presents the results of a detailed engineering study of the existing Purba Saidpur Grid s PDB/PBS 33 kV network preparatory to installation and integration of a 5 * 1 MW Rice Husk power plant. Dinajpur PBS-1 receives all of its power supply from Power Development Board. Extremely poor reliability (largely due to load shedding) and low voltage levels of this power does not allow the PBS to deliver reliable, acceptable power quality to its consumers. The extremely poor voltage causes technical losses on the 33 kV networks of over 3.5% of power delivered.

This internship report has discussed the impact study of connecting a 5-MW Husk power generation plant into the sub-transmission system of a Dianjpur PBS-1 and showed that the single most significant improvement would be to increase MW supply power and voltage by installing a 5*1 MW plant at the near to Utrail feeder. Once the husk plant power merge into the 33 existing grid the shortage of power at the peak time will decrease significantly in the Dinajpur PBS.

This report also presents several different approaches to compensate reactive power absorbed by the induction generator and mitigate voltage sag issues. Losses on the sub-transmission lines for the existing system with existing loading added up to 1,600 kW. These losses increased to 2,915 kW when projected loading was added to the existing system. Once the Husk power generation plant start generation and start supply to the existing grid with the changes proposed in this paper were implemented, losses were reduced to 950 kW in base case system. Further big improvements will not require within next five years. The procedures for system analysis and potential issues mitigation approaches described in this paper can be referenced for this type of development in other part of Bangladesh. The assignment completed in this Undergraduate s internship can be used to determine the ratings of the generator which can be connected at a certain point while maintaining the voltage limits and the power quality in the grid.

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# Appendix A: Statement of Work NRECA

## Statement of Work

NRECA agrees to engage Ms. Rumana Tarin as an intern to provide support for the development of an electric utility model.

### Scope

Ms. Tarin will carry out the following tasks:

Ms. Tarin shall coordinate with the NRECA Engineering and GIS team to obtain the best available maps of the Electric Utility systems to be modelled, and shall prepare and evaluate power flow models of system as selected by the Supervisor (from NRECA Engineering Team). Ms. Tarin shall modify the models as required so that they provide adequate voltage service throughout the duration of the proposed projects (5 Years) and shall prepare a list of improvements necessary to meet the performance requirements.

### Deliverable

Ms. Tarin will present a report on her findings and a written detailed work plan.

### Technical Direction

Ms. Tarin will work in coordination with and under the general supervision of Mr. Md Hasibur Rahman, Project Engineer of NRECA.

### Term

This Agreement is effective for all services rendered from the period beginning September, 2010 and ending November, 2010 unless extended in writing by both parties.

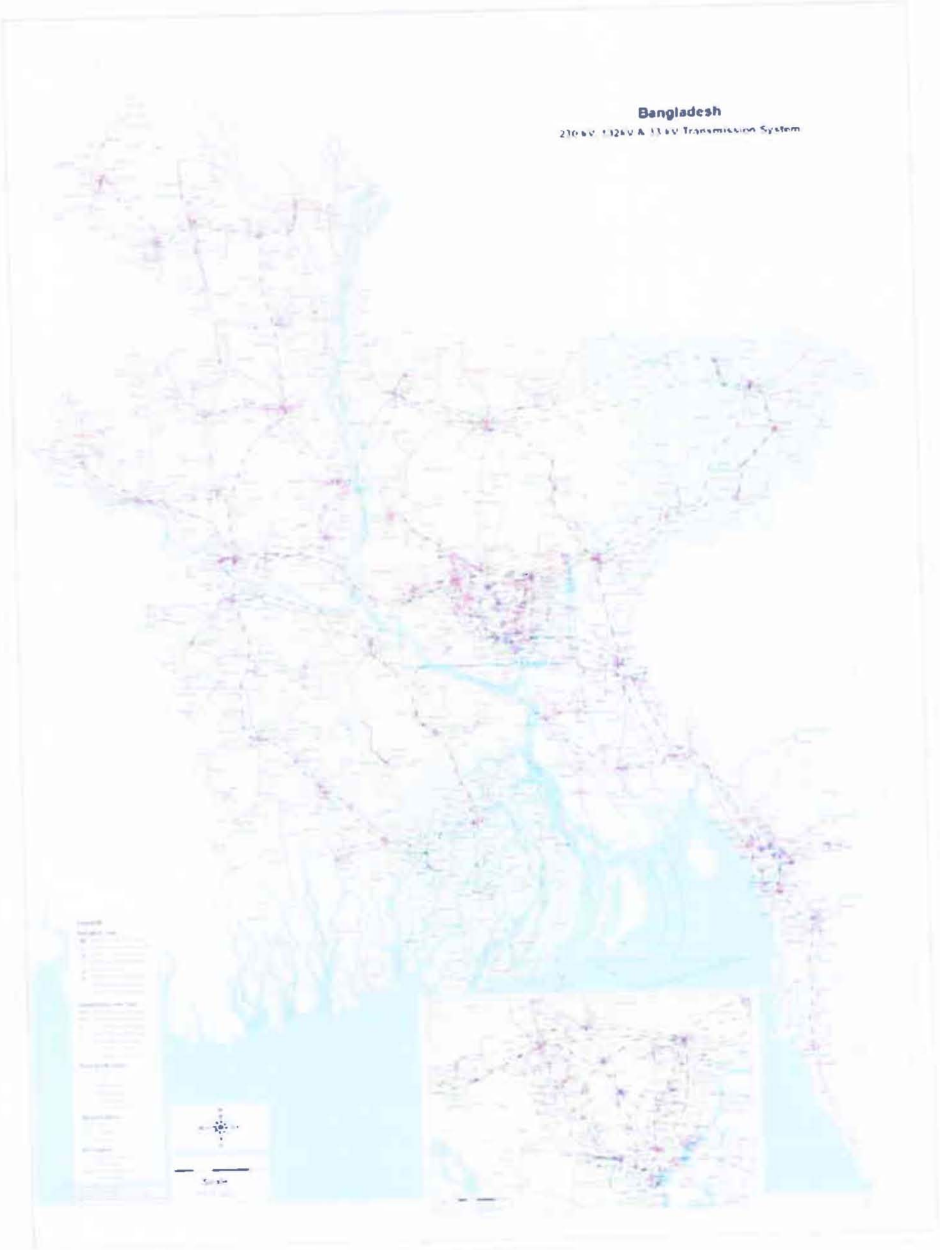
### Work Schedule

Ms. Tarin will usually work during the normal work week, as recognized by NRECA, from Sunday through Thursday. The work day will be between 8:00 AM and 4:30 PM. During work day Ms. Tarin will be allowed to join her routine classes at her University.

### Honorarium

For all services rendered under this Agreement, NRECA shall give a token honorarium after successfully completion and submission of the final report.

# ppendix B: Map of Bangladesh Showing Electric Network



# Appendix C: Voltage Drop Simulation Results

## Simulation result for case A

```
Balanced Voltage Drop Report
                                                                      Source: PURBA SADIPUR
Database:PURBA SAIDPUR GRID EXISTING SYSTEM-CASE A.WM\
                                                                                                    12/07/2010  11:20  Page 1
-----------------------------------------------------------------------------------------------------------------------------------------
                                                                      Units Displayed In Percent
                                                                        -Base Voltage:100.0-
                                                  Type/   Pri      Base  Element   Accum    Thru   %    Thru             %    kW      %     From     Length
Element Name      Parent Name       Cnf  Conductor  kV       Volt  Drop      Drop     Amps  Cap   KW      KVAR    PF   Loss    Loss   Src      (km)
-----------------------------------------------------------------------------------------------------------------------------------
  PURBA SADIPUR                     ABC  PURBA SAID 76.21Y 100.0    0.00      0.00  217.92    0  44961   21524   90    0.00    0.0    0.000   0.000
L Purba_2X25/41    PURBA SADIPUR    ABC  Transforme 18.04Y  92.7    2.32      2.32  217.92  125  44961   21524   90  327.78    0.7    0.000   0.000
L OH1540           VNHB-30          ABC  477 MCM AC 18.08Y  92.9    2.11      2.11  491.08   73  26081   10376   93  702.60    2.7    8.000   8.000
L Psp_H/Q_3        OH1540           ABC  #4/0 ACSR  18.06Y  92.8    0.09      2.20  108.93   32   5713    1504   97    3.94    0.1    8.400   0.400
L PBS HQ 10 MV...  Psp_H/Q_3        ABC  Node       18.06Y  92.8    0.00      2.20  108.93    0   5709    1499   97    0.00    0.0    8.400   0.400
L OH1636           OH1540           ABC  477 MCM AC 17.67Y  92.8    2.13      7.25  382.55   57  19663    6622   95  240.78    1.2   12.500   2.500
 OH1637          OH1636           ABC  477 MCM AC 17.38Y  91.2    1.55     8.79  382.65  57  19422    5860   96 181.98   0.9  12.900  3.400
L OH1627           OH1637           ABC  477 MCM AC 17.22Y  90.4    0.81      9.60  247.60   37  12426    3495   96   62.76    0.5   18.700   2.800
L Psp_H/Q_2/1      OH1627           ABC  477 MCM AC 17.13Y  89.9    0.51     10.11  111.10   17   5543    1494   97   18.07    0.3   22.700   2.000
L UTHRAIL 10MV...  Psp_H/Q_2/1      ABC  Node       17.13Y  89.9    0.00     10.11  111.17    0   5525    1451   97    0.00    0.0   22.700   2.000
L OH1632           OH1627           ABC  477 MCM AC 17.19Y  90.2    0.16      9.76  136.56   20   6821    1807   97    6.82    0.1   19.700   1.000
L BALUBARI PDB...  OH1632           ABC  Node       17.19Y  90.2    0.00      9.76  136.57    0   6814    1789   97    0.00    0.0   19.700   1.000
L FAKIRAPARA 1...  OH1637           ABC  Node       17.38Y  91.2    0.00      8.79  132.13    0   6814    1789   97    0.00    0.0   12.900   1.000

-------------------------------------------------------------------------------------------------------------------------------------------
KEY->   L = Low Voltage     H = High Voltage     C = Capacity Over Limit     G = Generator Out of kvar Limits     P = Power Factor Low

         Load  Adjustment Capacitance    Charging  Gen&Motors Loops&Metas       Losses   No Load Losses      Total
KW      43361           0           0           0           0           0         1573            27.00      44961   Lowest Voltage = 89.89
KVAR    11386           0           0        -211           0           0        10349                       21524   Max Accm VoltD =  10.11
                                                                                                                     Max Elem VoltD =   2.32
-----------------------------------------------------------------------------------------------------------------------------------
Substation Summary:
   Substation              KW          KW Losses        KVAR        KVAR Losses       KVA         % Capacity
-----------------------------------------------------------------------------------------------------------------------------------------
PURBA SADIPUR          44932.00        1600.00       21732.00       10349.00       49847.45          0.00
-----------------------------------------------------------------------------------------------------------------------------------
Total:                 44932.00        1600.00       21732.00       10349.00       49847.45
-----------------------------------------------------------------------------------------------------------------------------------------
```

## Simulation result for case- B

```
                                                 Balanced Voltage Drop Report
                                                                      Source: PURBA SADIPUR

Database: PURBA SAIDPUR GRID AFTER FIVE YEARS SYSTEM-CASE B.WM\
                                                                                                           12/07/2010  11:26  Page 1
-----------------------------------------------------------------------------------------------------------------------------------
                                                                      Units Displayed In Percent
                                                                        -Base Voltage:100.0-                                km
                                               Type/      Pri     Base  Element  Accum    Thru    %    Thru            %    kW      %     From   Length
Element Name       Parent Name        Cnf  Conductor   kV      Volt  Drop     Drop     Amps   Cap   KW      KVAR   PF   Loss    Loss   Src    (km)
------------------------------------------------------------------------------------------------------------------------------------------------------
  PURBA SADIPUR                       ABC  PURBA SAID  76.21Y 100.0   0.00     0.00  298.39    0  59282   33809   87    0.00   0.0    0.000  0.000
L Purba_2X25/41    PURBA SADIPUR      ABC  Transforme  17.51Y  91.9   8.08     8.08  298.39  171  59282   33809   87  590.95   1.0    0.000  0.000
L OH1540           VNHB-30            ABC  477 MCM AC  17.68Y  92.8   7.22     7.22  663.48   99  34554   15626   91 1287.62    3.7   8.000  8.000
L Psp_H/Q_3        OH1540             ABC  #4/0 ACSR   17.65Y  92.7   0.12     7.34  142.87   43   7428    1960   97    6.96   0.1    8.400  0.400
L PBS HQ 10 MV...  Psp_H/Q_3          ABC  Node        17.65Y  92.7   0.00     7.34  142.88    0   7421    1949   97    0.00   0.0    8.400  0.400
L OH1636           OH1540             ABC  477 MCM AC  17.11Y  89.8   2.99    10.21  519.33   78  25838    9531   94  443.66   1.7   12.500  2.500
L OH1637           OH1636             ABC  477 MCM AC  16.70Y  87.7   2.13    12.34  519.44   78  25394    8111   95  332.29   1.3   12.900  3.400
L OH1627           OH1637             ABC  477 MCM AC  16.49Y  86.5   1.11    13.45  336.76   50  16201    4711   96  116.07   0.7   18.700  2.800
L Psp_H/Q_2/1      OH1627             ABC  477 MCM AC  16.36Y  82.8   0.70    12.15  151.25   23   7215    1981   96   33.48   0.5   22.700  2.000
L UTHRAIL 10MV...  Psp_H/Q_2/1        ABC  Node        16.36Y  82.8   0.00    12.15  151.32    0   7182    1886   97    0.00   0.0   22.700  2.000
L OH1632           OH1627             ABC  477 MCM AC  16.45Y  86.3   0.21    13.66  182.56   28   8870    2364   97   12.58   0.1   19.700  1.000
L BALUBARI PDB...  OH1632             ABC  Node        16.45Y  86.3   0.00    13.66  182.58    0   8857    2326   97    0.00   0.0   19.700  1.000
L FAKIRAPARA 1...  OH1637             ABC  Node        16.70Y  87.7   0.00    12.34  182.79    0   8858    2326   97    0.00   0.0   12.900  1.000

-----------------------------------------------------------------------------------------------------------------------------------------
KEY->    L = Low Voltage      H = High Voltage     C = Capacity Over Limit     G = Generator Out of kvar Limits     P = Power Factor Low

        Load  Adjustment Capacitance    Charging  Gen&Motors Loops&Metas      Losses  No Load Losses      Total
KW      56370          0           0           0           0           0        2888           27.00      59282   Lowest Voltage = 82.85
KVAR    14801          0           0        -206           0           0       19212                      33809   Max Accm VoltD =  12.15
                                                                                                                  Max Elem VoltD =   8.08
------------------------------------------------------------------------------------------------------------------------
Substation Summary:
  Substation             KW            KW Losses        KVAR        KVAR Losses       KVA          % Capacity
------------------------------------------------------------------------------------------------------------------------
PURBA SADIPUR          59258.00        2912.00        34013.00       19212.00       68242.55          0.00
------------------------------------------------------------------------------------------------------------------------
Total:                 59258.00        2912.00        34013.00       19212.00       68242.55
------------------------------------------------------------------------------------------------------------------------
```

## Simulation result for Case- C

```
                                                                  Balanced Voltage Drop Report
                                                                      Source: PURBA SADIPUR

Database: D:\33 KV PURBA SAIDPUR GRID INCLUDING HUSK GENERATION PLANT.WM\
                                                                                                          12/07/2010  11:31  Page 1
------------------------------------------------------------------------------------------------------------------------------------------
                                                                      Units Displayed In Percent
                                                                        -Base Voltage:100.0-                                -
                                           Type/      Pri    Base  Element  Accum    Thru   %    Thru           %   kW       %    From    Length
Element Name     Parent Name      Cnf  Conductor  kV     Volt  Drop     Drop     Amps  Cap   KW      KVAR   PF   Loss     Loss  Src     (km)
------------------------------------------------------------------------------------------------------------------------------------------
  PURBA SADIPUR                   ABC  PURBA SAID 76.21Y 100.0    0.00     0.00  178.37   0  39338  10950   96   0.00    0.0   0.000  0.000
  BALUBARI PDB... REG1448         ABC  _DefaultBa 19.05Y 100.0    0.00     0.00  116.79   0   6457   1695   97   0.00    0.0   0.000  0.000
  PBS_Feeder_2    REG1448         ABC  _DefaultBa 19.05Y 100.0    0.00     0.00  142.25   0   8027   2119   97   0.00    0.0   0.000  0.000
C OH1540          VNHB-30         ABC  477 MCM AC 18.63Y  97.8    2.21     2.21  360.65  54  20557   1867  100 380.56    1.9   8.000  8.000
P Rice Husk Pl... Rice Husk Plant ABC  477 MCM AC 18.46Y  96.9   -0.00     3.13 -149.49  22  -4942  -6618   60   0.00    0.0  17.251  0.000
P XFMR1641        Rice Husk Pl... ABC  Transforme  6.32Y  99.5   -2.66     0.47 -149.49  57  -4942  -6618   60  57.68    1.2  17.251  0.000
P NEWCAP-1FA60958 XFMR1641        ABC  Cap (4500)  6.32Y  99.5    0.00     0.47 -232.08   0      0  -4458    0   0.00    0.0  17.251  0.000

------------------------------------------------------------------------------------------------------------------------------------------
KEY->    L = Low Voltage     H = High Voltage     C = Capacity Over Limit    G = Generator Out of kvar Limits    P = Power Factor Low

         Load  Adjustment Capacitance    Charging  Gen&Motors Loops&Metas       Losses   No Load Losses      Total
KW      43361           0           0           0       -5000           0          922            52.00      39338   Lowest Voltage = 96.00
KVAR    11386           0       -4458        -220       -2422           0         6664                       10950   Max Accm VoltD =  2.00
                                                                                                                      Max Elem VoltD =  2.74
------------------------------------------------------------------------------------------------------------------------------------------
Substation Summary:
   Substation           KW           KW Losses        KVAR        KVAR Losses      KVA          % Capacity
------------------------------------------------------------------------------------------------------------------------------------------
PURBA SADIPUR        39283.00          977.00      15628.00         6662.00      40833.62          0.00
------------------------------------------------------------------------------------------------------------------------------------------
Total:               39283.00          977.00      15628.00         6662.00      40833.62
------------------------------------------------------------------------------------------------------------------------------------------
```