ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING

STUDIES ON APPLICATIONS OF FACTS DEVICES TO IMPROVE OVERLOADING AND UNBALANCED POWER SYSTEM OPERATING CONDITONS ON ETHIOPIAN GRID

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Declaration

I, the undersigned declare that this thesis is my original work, has not been presented for Degree in this or other universities, all sources of materials for this thesis have been fully acknowledged

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This is certifying that the above statement made by the student is correct and true to the best of my knowledge and belief.

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Advisor's Name

Acknowledgment

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Acronyms

%	Percentage
ALA	Alaba
ASW	Active Smart Wire
DC	Direct Current
D-FACTS	Distributed FACTS
DOE	Department of Energy
DSI	Distributed Series Impedance
DSR	Distributed Series Reactance
DSSC	Distributed Series Static Compensator
DUM	Dummy
EEPG	Ethiopian Electric Power Grid
EHV	Extra High Voltage
EMS	Energy Management System
FACTS	Flexiable Alteranting Current Tranmission Systems
GRED	Great Renaisance Dam
GUI	Graphic User Interface
GW	Giga Watt
HV	High Voltage
km	Kilometer
kV	Kilo volt
M$	Million United States Dollar
MVAr	Mega Volt Amper
MW	Mega Watt

NGCC	National Grid Control Center
OPF	Optimal Power Flow
PSS/E	Power System Simulator for Engineers
pu	Per uint
R	Resistance
RAS	Remidal Action Sechme
S	Apparent Power
SPS	Special Protection Secheme
T&D	Transmission and Distribution
TVA	Tensase Valley Autority
U.S	United States
USD	United States Dollar
V	Voltage
VAR	Volt Amper
WS2	Wolyta Sodo Two
Z	Impedance
μH	Micro Henery

Abstract

An important issue in today's power system is the need to analyze and determine the adequacy of transmission capacity. There is a need for approaches to increase transmission system capacity without construction of new transmission facilities, all while assuring secure operation of the grid. Smart grid technologies such as FACTS and DSRs can enhance capacity utilization and increase flexibility in controlling power flows on transmission lines.

Distributed Series Reactor (DSR) control is a new smart grid technology that can be applied to control flows in the transmission system. DSRs can be used to balance flows in a single line as well as to control the distribution of power flows in parallel lines. This thesis investigates the application of Distributed Series Reactors (DSRs) on Ethiopian National Grid transmission systems to control power flow and to improve the overloaded line capacity and shifting power to other parallel branches which are under loaded. Simulation studies are carried out on Ethiopian grid using power system simulation for Engineers (PSS/E). 400kV, 230kV and 132 kV transmission lines of the Ethiopian gird are considered for simulation studies.

Placement of a DSR having its reactance value 20% of the overloaded line enhances the existing transmission capacity utilization of the 400kV lines by 89.22%, for the 230kV lines by 81.28% and the same for 132kV lines by 83.79%. Moreover, the overloading condition of the 132kV line is improved by 95%.

Placement of a DSR having its reactance value 30% of the overloaded line enhances the existing transmission capacity utilization of the 400kV lines by 89.22%, the 230kV lines by 81.32% and the same for 132kV lines by 82.42%. Moreover, the overloading condition of the 132kV line is improved by 85%.

Placement of a DSR having its reactance value 50% of the overloaded line enhances the existing transmission capacity utilization of the 400kV lines by 89.22%, the 230kV lines by 81.31% and the 132kV lines by 80.13%. Moreover, the overloading condition of the 132kV line is improved by 79%.

In this study cost benefit analysis of DSR placement having its reactance value 20% of the overloaded line is performed. The cost benefit analysis for the construction of new transmission line for 84.76% capacity improvement needs 12.25M$ and the total cost for the same capacity improvement using DSRs are deployed on the overloaded line needs 3.33M$. Comparing this total cost of DSRs which is 3.33M$ with that of building new lines which is 12.25M$, it appears that the DSRs implementation cost reduced by 27.18 % relative to the traditional approach of building new lines.

Key Words: Distributed Series Reactance (DSR), Ethiopian Transmission System, Power transfer capacity, Overloaded Lines and Cost Benefit Analysis.

CHAPTER 1
INTRODUCTION

1.1 Background

In recent years, Ethiopian grid system has been progressed in rapid development and expansion processes. Many big hydro power plants and very long EHV transmission lines has been added to the grid to serve the fast-growing economy of the country, also in the near future many more power plants and transmissions systems are expected to be connected with the power grid.

Interconnections and power trading with other control areas (neighboring countries), Sudan and Djibouti have been realized, enabling robustness and dynamicity of the grid. Further, power grid interconnectors will be available in the east African regions, example Ethio-kenya, Ethio-Sudan-Egypt, etc.

Since, Ethiopia has a great deal of hydro and wind power potential, the interconnectors will create opportunities for foreign electricity market, mainly to sell electricity to east African countries. Apart from this the interconnectors will have mutual benefits for reliability and security of the interconnected grid system itself and social-economical & political stability of the region.

In the last two decades local customers of EEP ranging from very big industries to small household customers, their demand for electric power is growing at a very fast rate. Foreign investment policy of the country is highly attractive and due to this various type of new industries are booming & being operational. To serve this vast electric power demand, improving existing power grid reliability and security is mandatory & highly essential.

Currently, EEU customers get access for electricity either through the National Electric Power Grid or through the Off-Grid system. The former is the most dynamic, robust and very huge interconnected electricity infrastructure supplying most urban areas, being the backbone for industrialization and economic transformation, also having interconnectors with other National Power Grid (neighboring countries) for electricity export and trading. The later one is very small, self-contained system (SCS) supplying electricity to remote and localized areas very far from existing national grid system.

The Ethiopian National Grid is 100% powered by renewable energy resources mainly coming from hydro and wind power plants. Installed capacity of Hydro power plants is 2657MW, Wind power plant 328MW and others. In addition, GRED hydro power project having a capacity of 6000MW is also expected to be connected stage by stage. In the year 2020 the total installed capacity of the Ethiopian National Grid will be more than **10,000MW** [1].

There are **155** number of substation under transmission substation operation department, and **19** number of power plant substation managed by Generation operation department. Therefore, in total there are **174** number of substation in the grid system including 500/400/230/132/66/45/33/15kV substations. The Ethiopian National Grid Control Center-NGCC is responsible for the grid reliability operation & coordination.

A recent Department of Energy (DOE) report highlights the problem of congestion in transmission lines near major metropolitan centers. Transmission network infrastructures face much more public opposition and as a result take longer to get approvals and land for the construction of newlines. As the load continues to increase it is possible that the transmission network may not be able to keep up with the increase of the load.

In transmission system planning projects, the cost of congestions often a consideration. Building new transmission lines may not be the most cost effective approach to alleviating congestion [2]. Many researchers have looked for a way to control power flow that is less costly than building new lines. For some cases, the only solution to control flow is to invest in new lines; A few studies [3] investigate several different methods for controlling power flow. Other authors use series and shunt compensator devices to control power flow. Other studies [4] propose using flexible alternating current transmission system devices, but these devices are expensive for large area implementations, but in some cases, there are other solutions. One new techniques for controlling power flow, distributed series reactors (DSRs), shows promise.

Distributed series reactors are lightweight devices that can be installed quickly on transmission lines [5]. Distributed series reactors can be used to increase the capacity of a transmission system by moving flow from heavily loaded lines to lines that are in parallel and which have unused capacity. This is accomplished by using the DSRs to increase the reactance of the heavily loaded lines. In the study here, DSRs are used as an alternative way to alleviate overloading problems, providing economic benefits overbuilding new transmission lines.

1.2 Statement of the Problem

The transmission system is the core part of power system network which deliver power to the distribution system. Maximize the capacity power flow on the transmission line plays a key role to reduce transmission networks take a much longer time to plan and construct and reduce investment on new lines, moreover getting transmissions line corridor has been a challenge specially in major cities like in Addis Ababa due to huge displacement cost are a head ache for the utility provider. The 132kV Alaba – Wolyta Sodo II transmission line which is connected to the 230kV and 400kV lines is overloaded and this line is connected to the maximum generating plant like Gibe III. It is a problem for using efficiently the 400kV lines which have a big capacity to transport more power to the load center. Moreover, it will be a cause for cascading failures for the power system. Analysis such kinds of problems on applications of FACTS devices to improve overloading and unbalanced conditions using Power system simulation software for Engineers (PSS/E) on existing power grid.

These days, the Ethiopian Electric Power grid is highly suffering from frequent blackouts, 15 number of blackout has been recorded in the year 2015 alone [1]. Most blackouts were the results of cascading failures of the power system due to some lines are overloaded. Preventing such blackouts is a very important goal that requires detail study, analysis & close monitoring of the state of the power flow

This thesis considers or focuses on problems of overloading and unbalanced operating conditions in 400kV, 230kV and 132kV transmission system of Ethiopian national grid and investigates the methods for solving the above problems as well as to enhance the power transfer capacity of the transmission system.

1.3 Objectives of the Thesis

General Objective

The general objective of this thesis is to analyze and investigate the unbalanced and overloaded operating conditions of Ethiopian national grid transmission system and to explore the applications of FACTS devices for alleviation of these problem as well as to enhance to its power transfer capacity.

Specific Objectives of the Thesis

The specific objectives of the thesis research are as follows:

- To evaluate and analyze the power transfer capacity 400kV, 230kV and 132kV transmission systems of Ethiopian national grid and identify the unbalanced and overloaded operating conditions.

- To investigate the mitigation of unbalanced and overloaded operating conditions of the transmission system using DSRs
- To determine the capacity and location of DSR to solve the overloaded and unbalanced operating conditions.
- To carry out simulation studies using PSS/E (power system simulation for engineers) and compare the power transfer capacity with the existing transmission system with that obtained using the proposed technique or method.
- To carry out cost benefit analysis of the existing system with implementation of DSR and the new transmission system with the same power transfer capacity.
- To draw relevant conclusions and make recommendations for improvement of capacity on transmission systems on Ethiopian power grid (EEPG)

1.4 Methodology

132kV, 230kV and 400kV transmission systems from existing Ethiopian national grid are considered for the study of overloaded and unbalanced power system operating conditions. The capacity improvement analysis has been carried out using Power System Simulation for Engineers (PSS/E) during peak load of 2017 of the grid. Two cases are evaluated during power flow study where the capacity enhancements on 400kV, 230kV and 132kV transmission system are determined. The cases are: (1) Power flow study without DSRs are used; (2) Power flow study with placement of DSRs having its reactance value 20%,30% and 50% are operated on the overloaded line in an attempt to better utilize the capacity of each line.

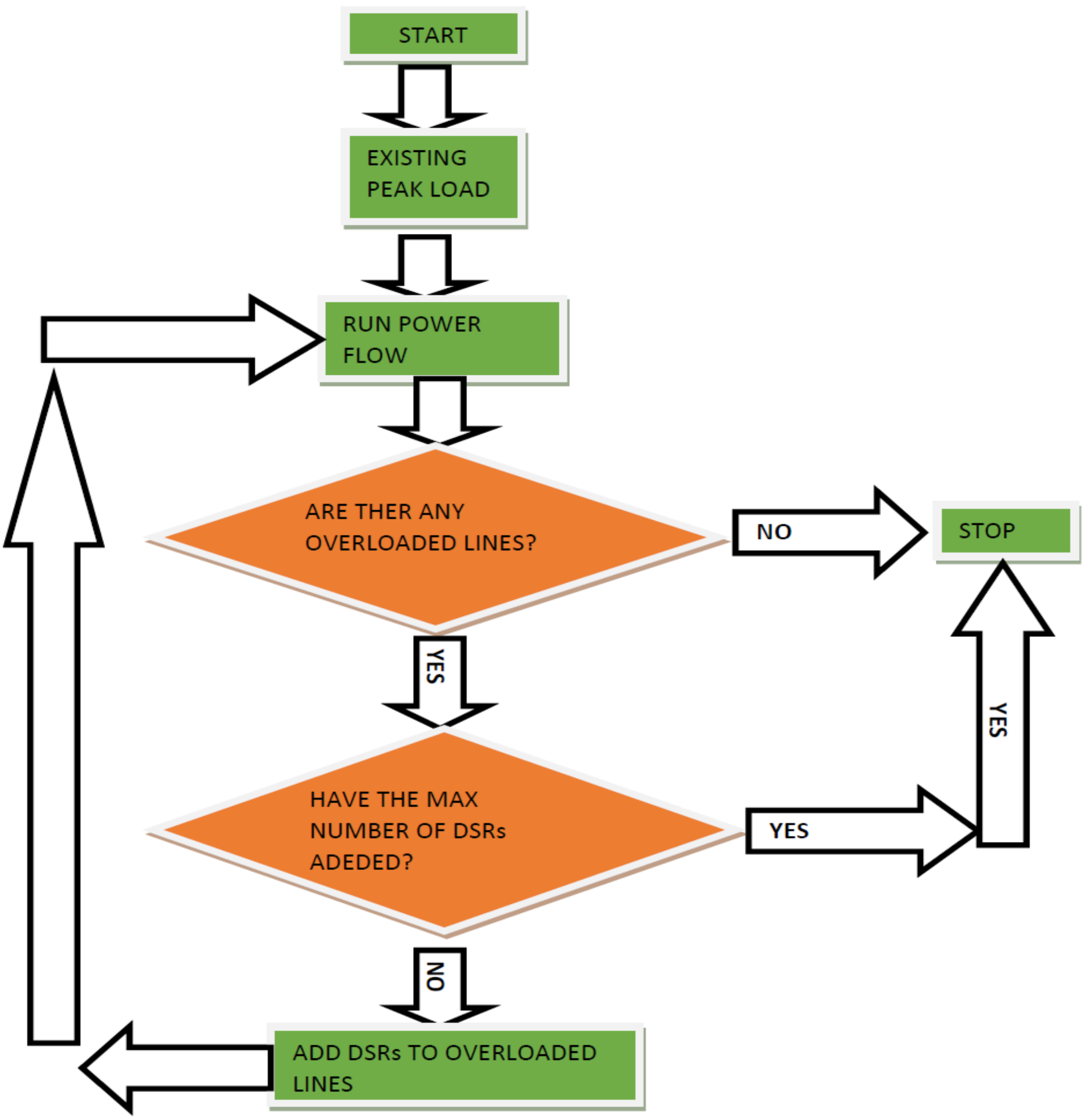


Figure 1- 1 DSR placing and operating flow chart

1.5 Literature Review

Initial field trials distributed series reactor implications for future applications presented by Bruce Rogers [25]. The Distributed Series Reactor is a self-contained device, powered by induction from a transmission line conductor that increases the series impedance of a circuit by injecting series reactance. The concept was first demonstrated in 2002 – 2003 and has been demonstrated in pilot installations on HV transmission lines. For a 161-kV line, assume 5 spans per mile and a device at each end of each span i.e. 10 devices per mile. Approximate impedance increase = 20%. An application had been tried on 39 bus system gird for a base line 1904 MW and increase the MW to 638 (33.5%) and line availability from 59 % to 93% using distributed series reactance.

The pilot test results: -

- Total Impedance Increase (33 DSRs / Phase @ 47 μH / DSR): .226 % (degree of control limited by number of available devices and a test line that was longer than optimal for the demonstration)
- Devices also successfully used to adjust phase imbalance
- Single point failure of communication system identified for necessary design upgrade
- DSRs presently considered unsuitable for bundled conductor use, although technically feasible
- Simplest application is reduction of maximum contingency load for postponement of line up rate
- Ability to quickly relocate DSRs reduces cost to individual projects
- Future designs may provide capacitive injection to reduce reactive impedance
- Future designs with high speed controls may be low cost alternative to FACTS

Load growth and power flow control with DSRs: Balanced vs unbalanced transmission networks, Shamia Omran [26]. A new smart grid technology, the Distributed Series Reactor (DSRs), is investigated in this paper. DSRs can be used to balance flows in the phases of an unbalanced line or used to control the distribution of flow in a meshed network. In this paper, DSRs will be used to alleviate overloads that result due to increased load. The design is performed for an unbalanced, 3-phase system, and then for a balanced, 3-phase model derived from the unbalanced model, where the symmetrical components transformation is used to create the balanced model.

- The authors have created 3-phase models of transmission systems for 7 different utilities in the U.S., where some of the transmission systems spanned multiple states, and included volt-age levels of 230 kV, 345 kV, and 500 kV, where the majority of the lines were not transposed. In several utilities there were no transposed lines in the transmission systems. The reasons for imbalance at the receiving end of a line can be due to impedance unbalance, load unbalance, and sending end voltage unbalance. This paper only addresses impedance unbalance, but as demonstrated in the case study in the paper, the effects of impedance unbalance (i.e., non-transposed lines) can be significant on flows and voltages. Thus, to investigate the effect on DSR design of the line impedance model, two cases are considered, an unbalanced, 3-phase impedance model, and a balanced, 3-phase impedance model. The balanced model is derived by assuming that the lines in the unbalanced model are transposed. In the unbalanced model the self-impedances are unequal with symmetrical but unequal off diagonal elements. The same is true for the shunt admittance matrix of the unbalanced model. In the balanced model the impedance matrix has diagonal elements that are equal in value and off diagonal elements that are zero

  The author investigates:

- The overloads start to occur in the balanced model at 141% load growth, whereas overloads do not occur in the unbalanced model until 145% load growth is reached. At the 141% and 143% load levels, the unbalanced model has no overloads and no DSRs are needed. However, the balanced model experiences overloads at the 141% and 143% load levels, where75 DSRs and 900 DSRs are required, respectively. This is quite a significant difference between the 2 models.

- At the 149% load level, 3750 DSRs are deployed in the unbalanced model to alleviate overloads whereas in the balanced mode l5550 DSRs are deployed
- For a given loading, use of the balanced model in the design results in many more DSRs for control than when the unbalanced model is used in the design. It was shown that the balanced model assumption, if used when lines are truly unbalanced, can lead to significant errors.
- The majority of the transmission system in the U.S. is unbalanced, and since significant errors can arise when just the impedance unbalance is considered.
- The application of DSRs can increase the utilization of the line capacity in a system. This increased utilization can delay or eliminate the need for building new transmission lines. Whether DSRs should be used to increase line utilization or new lines should be built is partly an economic question.

Investigation of distributed series reactors in power system applications and its economic implementation by Ahmet Onen [27]. The transmission system expansion planning process requires lots of calculations looking many years into the future, and the results are based on assumed load growth. If the load growth assumed in the planning process is not correct and unexpected load growth occurs for some load points, the transmission system could face serious congestion and even overloading problems.

In this paper, transmission line impedance adjustment techniques using distributed series reactance (DSR) is considered. The IEEE39 bus transmission system used in this work. Line ratings, line lengths, and load flows for the system have been taken. The DSR congestion relief factor is defined as the rate of maximum system loading without DSRs to the maximum system loading with DSRs, as given by equation (2.13)

$$\text{DSRCongestionReliefFactor} = \frac{\text{LoadingWithoutDSR}}{\text{LoadingwithDSR}} \quad (2.13)$$

This study represents a new control method of power flow by using DSR modules. Algorithm is tested on the IEEE New England (39bus) test system. The results and observations with the DSR algorithm are stated here:

- The proposed algorithm with DSR modules can be used to manage power flow and capacity expansion and reduce overloads when some areas require special load growth.
- The proposed algorithm with DSRs is tested for constant load growth applied to each bus, and the results show that the proposed algorithm is also useful for entire-system expansion planning
- Single contingency of generation outage is tested with the proposed algorithm. The results show that the proposed algorithm fully utilizes the capacity of the existing system by using DSRs when generation outages occurred
- Line outages are also tested with the proposed algorithm and one of the largest lines was taken out by considering the worst case; the results show that the DSR algorithm can utilize capacity effectively, when there are line outages and also overloading problems when there is a line contingency as well.
- Simulation results show the practicability and success of the DSR technique as a control for power flow in providing a cheaper alternative to the construction of new transmission lines.

Feasibility of DSR applications in transmission grid operation—Control of power flow and imbalanced voltage by Mohammad Nawaf Nazira,[*], Shaimaa Omran[a], Robert Broadwater[b] [31]. This paper studied the application of Distributed Series Reactors(DSRs) in increasing transmission capacity and reducing voltage imbalance in unbalanced transmission networks. The IEEE 39 bus standard transmission system model was modified to a 3-phase, unbalanced, model consisting of lines operating at 230 kV, 345 kV and 500 kV.

It was shown that as the network load is increased and with-out employing DSRs, the full capacity of the transmission network was underutilized as the low voltage line, the

230 kV line, over-loaded first, and the high voltage line, the 345 KV line, was left with significant unused transmission capacity. In order to increase the utilization of the high voltage line, DSRs are added to the low volt-age line, and this has the effect of pushing more power toward the alternate high voltage path.

With the unbalanced transmission lines evaluated, it is found that unsymmetrical operation of DSRs is more beneficial than symmetrical operation. With the unsymmetrical operation only half the number of DSRs is needed to achieve the same trans-mission capacity increase. Hence, unbalanced operation of DSRs over the phases of the low voltage line can result in substantial transmission capacity increase while using substantially fewer DSRs.

The economic analysis for symmetrical and unsymmetrical operation of DSRs demonstrated significant potential economic benefits from using DSRs.

The second part of the paper studied the application of DSRs to reduce voltage imbalance. In applications where reducing the voltage imbalance rather than increasing the transmission capacity is the main objective, DSRs can also be useful.

The modified 3-phase, IEEE 39 bus system is again used to study the voltage imbalance. In this case a 345 KV line in parallel with a 500 KV line was considered. It is found that under certain unsymmetrical DSR operation on the500 kV line, the voltage imbalance at the receiving end of the line can be reduced from 0.275% to about 0.008%.

1.6 Organization of the Thesis

The thesis is organized into five Chapters:

In chapter 1 is an introductory part giving background of the study. The basic problem is described. The objectives of the thesis work are stated. The methodologies are clearly described and finally researchers done in the area of the application of distributed series reactance have been discussed in detail. In Chapter 2 deals with fundamentals of FACTS Controllers deeply assessed. Different kinds of FACTS controllers and the basic principle have been discussed. The concept of using a distributed series compensator to control the power flow and the proposed power flow controller in this study clearly described.

In chapter 3, Ethiopian grid existing transmission system overview is evaluated. Overloaded and under loaded lines are identified at peak load power flow. Placement of distributed series reactance on overloaded line is conducted.

In Chapter 4 is simulation Studies using power system simulator for engineers (PSS/E) are carried out on the overloaded line. Performance evaluations without DSR and with DSR with regarding to capacity improvements of the 400kV, 230kVand 132kV transmission system have been investigated. The cost benefits Analysis of DSR with regard to construction of new transmission line is conducted.

Finally, conclusions, recommendations, and future researches are discussed in chapter 5. Results obtained from the thesis work are summarized and relevant conclusions have been drawn. Possible solutions for the problems during the thesis work have been recommended and future works in the area of the application of DSRs are proposed.

CHAPTER 2

FUNDAMENTALS OF FACTS CONTROLLERS

2.1 Introduction

In its most general expression, the FACTS concept is based on the substantial incorporation of power electronic devices and methods into the high-voltage side of the network, to make it electronically controllable. Many of the ideas upon which the foundation of FACTS rests evolved over a period of many decades. Nevertheless, FACTS, an integrated philosophy, is a novel concept that was brought to fruition during the 1980s [6]. FACTS look at ways of capitalizing on the many breakthroughs taking place in the area of high-voltage and high current power electronics, aiming at increasing the control of power flows in the high voltage side of the network during both steady-state and transient conditions. The new reality of making the power network electronically controllable has started to alter the way power plant equipment is designed and built as well as the thinking and procedures that go into the planning and operation of transmission and distribution networks. These developments may also affect the way energy transactions are conducted, as high-speed control of the path of the energy flow is now feasible. Owing to the many economical and technical benefits it promised, FACTS received the instinctive support of electrical equipment manufacturers, utilities, and research organizations around the world.

Several kinds of FACTS controllers have been commissioned in various parts of the world. The most popular are: load tap changers, phase angle regulators, static VAR compensators, thyristor-controlled series compensators, inter phase power controllers, static compensators, and unified power flow controllers. Providing the ability to control the flow of current can help the system operators to use the network resources more efficiently. State estimation and optimal power flow are such technique that adjusts line flows, by monitoring the prevailing system conditions, to extract the unused capacity from the grid.

The objective of state estimation is to estimate the unknown network quantities, which can be voltage magnitudes, phase angles, etc., from the quantities that are easily measurable such as generator's injected power, line reactance, transformer tap settings. [19, 20]

Optimal power flow simulations must be carried out every time the loading or the operating conditions on the network change. A central control and communication units are required to compute the new state of the system and adjust the control variables. Computational complexity and the requirement of an extensive communication capability make this approach difficult to implement for very large power networks

2.2 Types of FACTS Controllers

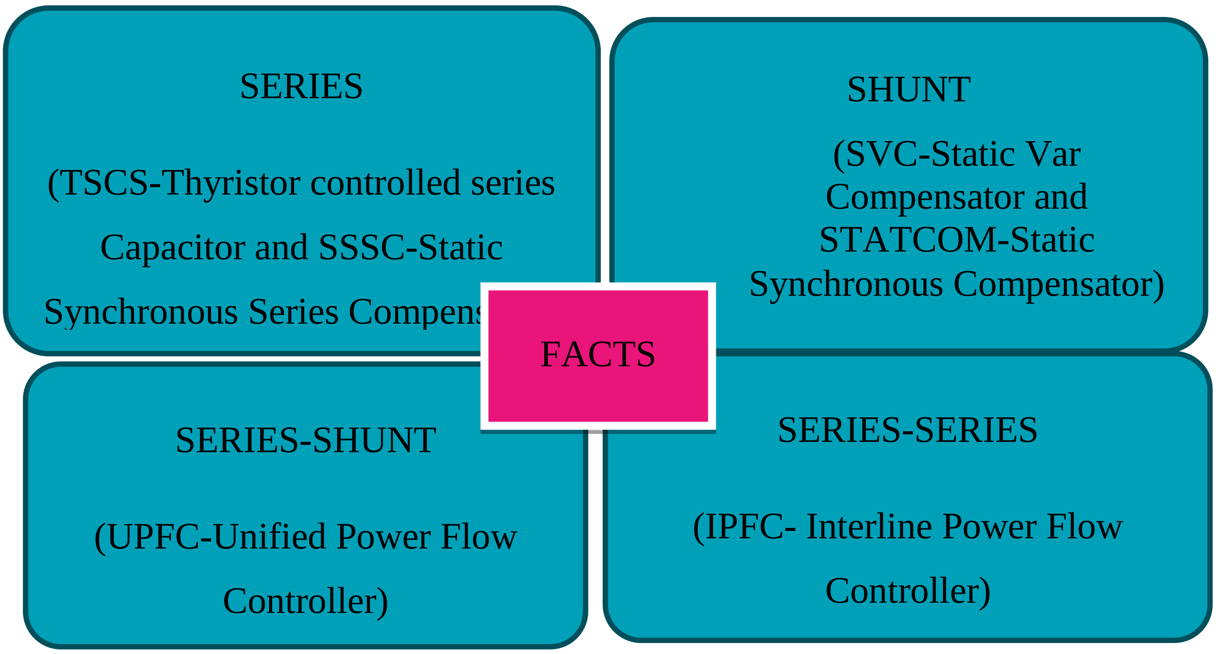


Figure 2-1 Types of FACTS controllers

FACTS devices change the system parameters, such as voltage magnitude, voltage angle, or the line reactance, to improve the transmission capacity and utilization of existing lines by controlling the flow of current through them.

Figure 2.2 shows a simple two bus system, with the associated parameters. The basic equation governing the flow of real and reactive power between the two buses/nodes is described by equations 2.1 and 2.2

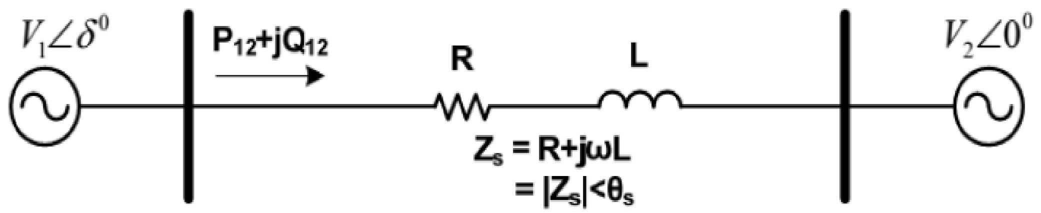


Figure 2-2 Two Bus System

$$P_{12} = V1V_2Z_S\cos(\theta_S - \delta) - \frac{{V_2}^2}{Z_S}\cos\theta_S \text{ Watt/Phase} \tag{2.1}$$

$$Q_{12} = \frac{V_1V_2}{Z_S}\sin(\theta_S - \delta) - \frac{{V_2}^2}{Z_S}\sin\theta_S \text{ Watt/Phase} \tag{2.2}$$

P_{12} and Q_{12}: the flow of real and reactive power from Bus 1 to Bus 2,

V_1 and V_2: the voltage magnitudes at the two buses,

δ: the phase difference between the voltages at the two buses,

$|Z_s|$: the absolute value of line impedance, and

θ_s: the angle of the line impedance

The equations can be further simplified if the line resistance (R) is neglected as shown in equations (2.3) and (2.4). This assumption holds true if the reactance of the line (X_L) is much greater than the resistance (R)

$$P_{12} = \frac{V_1 V_2}{X_L} \sin \delta$$

$$= \frac{V^2}{X_L} \sin \delta, \text{ if } |V_1| = |V_2| = |V| \qquad (2.3)$$

$$Q_{12} = \frac{V_1 V_2}{X_L} \cos \delta - \frac{{V_2}^2}{X_S}$$

$$= \frac{V^2}{X_L} (\cos \delta - 1) \text{ , if} |V_1| = |V_2| = |V| \qquad (2.4)$$

Here X_L is the line reactance

The equation highlights that both the real and reactive power flows between any two buses can be controlled by changing the voltage magnitudes, voltage phase difference, or the reactive impedance of the line. All FACTS devices alter one or more of these system parameters to control the flow of power. Controlling the power flow by changing the different parameters is presented in the following sections.

Series controllers

The series controller could be variable impedance, such as capacitor, reactor, etc., or power electronics based variable source of main frequency, sub synchronous and harmonic frequencies to serve the desired need. In principle, all the series controllers inject voltage in series with the line. Even variable impedance multiplied by the current flow throughout, represents an injected series voltage in the line. As long as the voltage is in phase quadrature with the line current, the series controller only supplies or consumes variable reactive power.

Shunt controllers

As in the case of series controllers, shunt controllers may be variable impedance, variable source or a combination of these. In principle all shunt controller inject current into the system. Even variable shunt impedance causes a variable current injection into the line. As long as injected current is in phase quadrature with the line voltage it supplies or consumes variable reactive power. Any other phase relationship will involve real power exchange also.

Combined Series – Series Controller

This could be a combination of separate series controllers, which are controlled in a coordinated manner, or it could be a unified controller. The series controllers could provide independent series reactive compensation but also could transfer real power among the lines via the power link (D.C link). The real power transfer capability of the unified series-series controller, referred to as interline power flow controller, makes it possible to balance both the real and reactive power flow in the lines. And there by maximize the utilization of the transmission system. Note that the term "unified" here means that the DC terminals of all controller converters are all connected together for real power transfer

Combined Series – Shunt Controller

This is a combination of series and shunt controllers which are controlled in a coordinated manner or a unified power flow controller with series and shunt elements. In principle combined shunt and series controller inject current in to the system with the shunt part of the controller and voltage in series in the line with the series part of the controller. However, when the shunt and series controllers are unified, there can be a real power exchange between the series and shunt controllers via the power link.

2.3 Distributed Series Reactance

As adjusting the impedance and admittance of the transmission line is one method to control the Power flow, Distributed Series Reactor controller was first proposed as a D-FACTS device to fulfill this objective. Lines that is likely to see overloads at certain times of the day or under Defined contingency conditions can be modified with DSR modules to automatically control the line reactance and thus current flow.

The DSR adds reactance to the self-impedance (diagonal elements of the impedance matrix) of the line model [7]. The DSR addition affects the self-impedance of the line impedance matrix Z where Z_{ii} = self-impedance of phase i, and i = A, B, C. Z_{ij} = mutual impedance between phases i and j, and i, j = A, B, C.

The value of the reactance added depends on the number of DSR modules activated and the selected reactance for each DSR module [8].

Distributed Series Reactors has been developed by a vendor working initially with the Tennessee Valley Authority (TVA) and the Department of Energy Advanced Research Program Agency -Electric (ARPA-E) [12]. DSRs are clamped to phase conductors and powered by induction from the line current. A magnetic link allows the device to inject inductive reactance to increase line impedance. In a meshed transmission grid, increased impedance in one path results in transfer of power flow to other paths [8]. The distributed series reactor, shown in Figure 2.5 [9], consists of a split transformer hung from the conductor. The conductor forms the primary winding of the transformer. When the secondary winding is shorted, the unit operates in monitoring mode and negligible inductance is coupled in series with the line. When the secondary winding is opened, the magnetizing inductance of the transformer is coupled in series with the line, and the unit operates in injection mode. While an individual device has a very small effect on the impedance of a line phase, adding numbers of them can change reactive impedance by several percent.

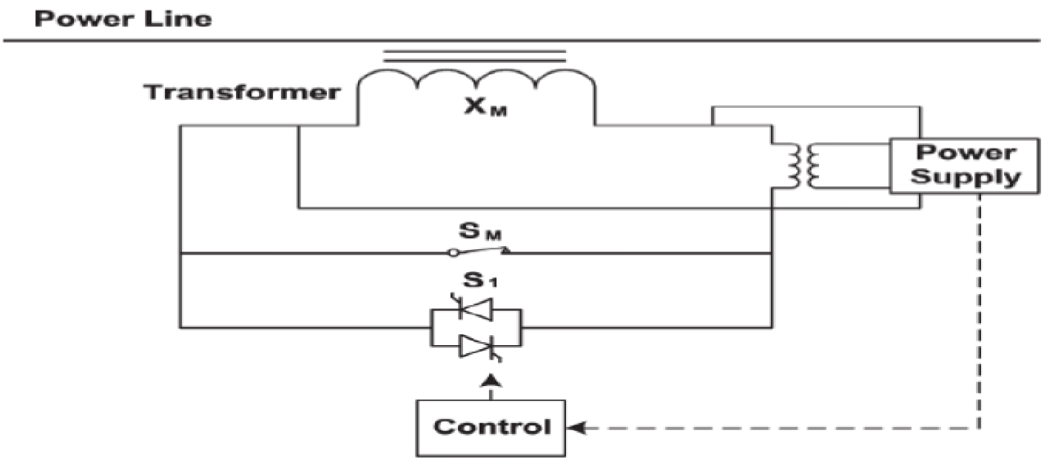


Figure 2 -3 Schematic Circuit of DSR [9]

Figure 2- 4 DSR connected to a transmission line [10]

DSR Installation

Fig. 2.6 shows a conceptual schematic of D-FACTS devices deployed on a power line to alter the power flow by changing the line impedance. Each module is rated at about 10 kVA and is clamped on the line, floating both electrically and mechanically. Each module can be controlled to increase or decrease the impedance of the line, or to leave it unaltered. With a large number of modules operating together, it is possible to have a significant impact on the overall power flow in the line. The low volt ampere ratings of the modules are in line with mass manufactured power electronics systems in the industrial drives and uninterruptible power supply markets and suggests that it would be possible to realize extremely low cost. Finally, the use of a large number of modules results in high system reliability, as system operation is not compromised by the failure of a small number of modules.

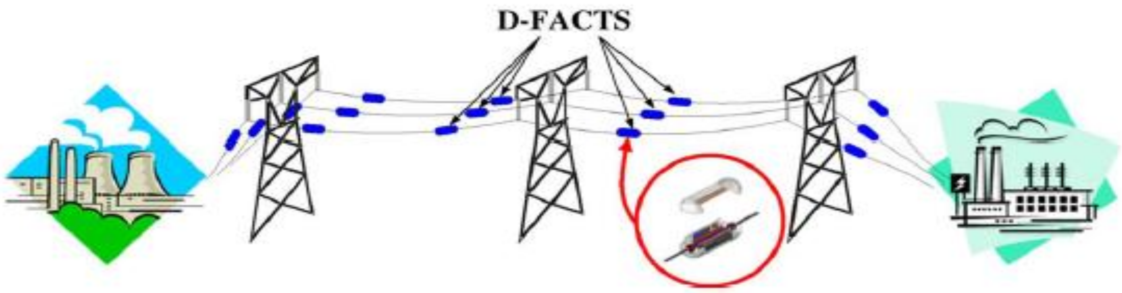


Figure 2- 5 D-FACTS deployed on power line

Equation (2.5) shows how power flow varies with the line reactance. Control of real power flow on the line thus requires that the angle δ or the line impedance XL be changed. A phase shifting transformer can be used to control the angle δ. This is an expensive non-scalable solution and provides limited dynamic control capability.

Alternatively, a single series compensator can be used to increase or decrease the effective reactive impedance XL of the line, thus allowing control of real power flow between the two buses. The impedance change can be effected by series injection of a passive capacitive or inductive element in the line. Alternatively, a static inverter can also be used to realize a controllable active lossless element such as a negative or positive inductor or a synchronous fundamental voltage that is orthogonal to the line current

$$P_{12} = \frac{V_1 V_2 \sin\delta}{X_L} \qquad (2.5)$$

Where V_1 and V_2 are the bus voltage magnitudes, δ is the voltage phase difference, and X_L is the line impedance. The concept of D-FACTS presents the highest potential to increase power flow and consequently the transfer capacity of a meshed transmission, sub transmission, and distribution network. In a meshed T&D network, the power transfer capacity of the system is constricted by the first line that reaches the thermal limit. The inability to effectively control power flow in such a network results in significant under-utilization of the overall system. D-FACTS devices offer the ability to improve the transfer capacity and grid utilization by routing power flow from overloaded lines to underutilized parts of the network. Capacitive compensation on underutilized lines would make them more receptive to the inflow of the current, while inductive compensation on overloaded lines would make them less attractive to current flow. In both cases, the throughput of the system is increased by diverting additional power flow from the congested parts of the network to the lines with available capacity.

Communication and Control

DSRs can be controlled in several ways. They can be pre-programmed to operate at a given current threshold, managed manually from an operating center in response to system conditions, or controlled automatically for more complex applications. Communications may be simply through one-way power line carrier, or two ways through cell phone circuits. Manual or automatic control is achieved as shown in Figure 2.7 through real-time communications. A Super DSR manages a set of proximate distributed series reactors and communicates with a DSR System Manager, which interfaces the entire fleet of DSRs with the energy management system (EMS). The central system manager allows configuring, monitoring and operating the DSRs as well as data archival. A DSR can provide line current, conductor temperature, fault location indication, fault current, ambient temperature, conductor vibration, conductor sag angle, and conductor blowout angle

When the DSR controller detects a fault, it returns the units to monitoring mode in less than 100microseconds to ensure that the DSRs do not interfere with existing protection schemes. To date, none of the DSR pilot deployments have required any changes to protection settings [11].

Applications include reliability improvement, delaying new line construction, reduction of congestion/ re-dispatch, simplification or removal of operating procedures, maintenance and construction outage support, phase balancing, and improved situational awareness

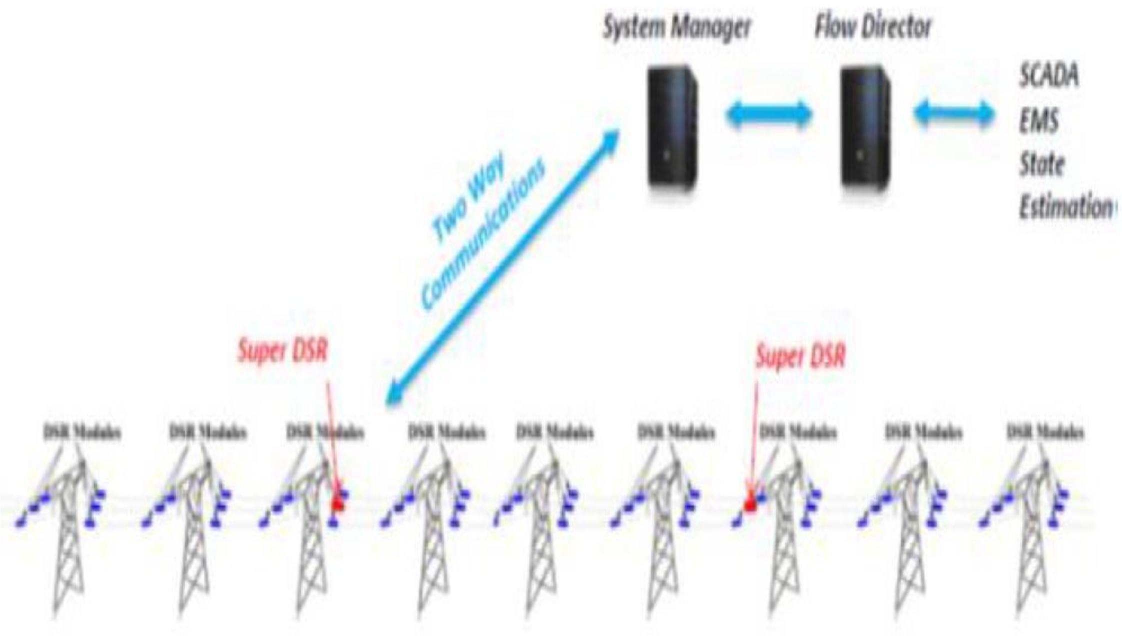


Figure 2-6 DSR communications

DSRs can be deployed to simplify or eliminate a remedial action scheme (RAS) or special protection scheme (SPS). In a study for a utility, a specific n-2 asset outage resulted in tripping generation and load with a RAS. Deploying DSRs on a number of transmission lines simplified the RAS and eliminated 1200 megawatts (MW) of generation and load shedding.

Pilot Test

Distributed Series Reactors has been developed by a vendor working initially with the Tennessee Valley Authority (TVA) and the Department of Energy Advanced Research Program Agency -Electric (ARPA-E) [12].

The first pilot test included 100 units installed over 17 spans of a 21-mile 161 kV line owned by the Tennessee Valley Authority. Installations averaged approximately 10 minutes per unit, including wire brushing the conductor, installation of protector rods, and installation of an associated vibration damper [11].

2.4 DSR for Power Flow Controller

The concept of using a distributed series compensator to control the power flow has been suggested earlier [12]. A distributed series compensator is capable of providing the same control capability as that of conventional series FACTS devices but at high module reliability and lower cost. However, the technology is based on a voltage source inverter, implying a high dependency on power electronics and electrolytic capacitors. The current power electronics devices are generally not suited for use in the utility environment. The safe operating temperature range of the commercially available power electronic and control devices is between 80^{o}C to 125^{o}C, while the temperature extreme for power line conductors (100^{o}C) can result in unsafe operating temperatures. Moving parts such as fans are not desirable making thermal management a major challenge as well. Further, the long-projected life (~30 years) suggests that dependence on electrolytic capacitors must be reduced. It is thus required to keep the power electronics at a minimal level to ensure a reliable system operation. Further, to realize the full control range of a distributed series compensator, a communication interface is required. In particular, a capacitive voltage injection can only be induced on a line if local information about the Operating limits of other lines is made available to the controller. Communication adds another layer of cost and complexity and degrades the system reliability.

The distributed compensator was proposed with the objective of providing a continuous control range, which translates into varying the impedance of the entire line over a desired range. The proposed power flow controller is based on this idea and is introduced as a subcategory of Distributed FACTS devices. The injection of series VARS is made possible through injection of series impedance (inductor or a capacitor).

A Distributed Series Impedance (DSI) can control active power flow by realizing variable line impedance. The transfer capacity and consequently the grid utilization can be improved by routing the power flow from overloaded lines to underutilized parts of the network. Capacitive compensation on under-utilized lines makes them more receptive to the inflow of current, while inductive compensation on over-loaded lines makes them less attractive to current flow. In both the cases, the throughput of the system is increased by diverting additional power flow from the congested parts of the network to the lines with available capacity.

However, as in the case of DSSC, bidirectional control capability requires a communication interface to instruct the device to operate in the particular mode. Communication adds another layer of to the complexity network and can further delay the adoption of the technology. A desirable control objective would be to make the modules switch in or out at a predetermined point, thus eliminating the need for centralized control. This can be easily realized if the control is made unidirectional, and the amount of injection can be related to locally measured quantities, namely current and/or voltage. The particular case that exhibits this characteristic is that of purely inductive injection. This implementation, where the injected impedance can only increase the line impedance is referred to as the Distributed Series Reactance.

The control strategy is unidirectional and the devices can be made to operate autonomously based on the measured line current

Using distributed Series Reactance (DSR), at a system level, as the current in a particular line exceeds a predetermined value, increasing numbers of DSR modules are switched in, gradually increasing line impedance and diverting current to under-utilized lines. Pre-selected lines that are likely to see overload conditions at certain times of the day or under defined contingency conditions can be modified with DSR modules to automatically control the current flow.

Deployment of DSR modules on a power system can thus help to steer current from one part of the network to the other. The utilization of all the lines in the network can be gradually increased, bringing the system to its maximum power transfer capacity. Reliability of the system is also enhanced with the ability to share the overload between lines. A DSR system can not only restore a secure system operation under contingency conditions by diverting the excess current to other lines but can also improve the transmission capacity under such conditions. Thus, a self-healing network with controllable values can be obtained.

CHAPTER 3

ETHIOPIAN GRID TRANSMISSION SYSTEM AND DISTRIBUTED SERIES REACTANCE PLACEMENT

3.1 Introduction

In this section, the Ethiopian Electric Power grid has been assessed for its system overview for different voltage levels, installed equipment's for enhancing system performance, modeling of the transmission system in PSS/E for analysis of contingency results and investigation partial blackout the peak load of 2017.The placement of DSR on the transmission line identified through system load flow simulation.

Ethiopian National Grid System

The country is divided into 8 regional operation departments for the electricity network: Addis Ababa, Central region, Eastern region, Northern region, North-Eastern region, North-Western region, Southern region and Western region.

The Ethiopian Electric Power is the sole power utility in Ethiopia responsible for power generation, and transmission electrical energy all over the country. EEP supports the endeavors of the Federal Government of Ethiopia in promoting social and economic progress in all parts of the country.

The most salient policies promoted by EEP to meet its strategic goals are listed below:

- Fast development within the country of competitively priced and environmentally sustainable electricity generation projects
- Exploitation of indigenous energy sources (estimated Ethiopian hydro power potential ≥ 45 GW)
- Participation of the private sector in the above-mentioned developments

The cost allocation for generation, transmission, distribution and supply shown on Fig 3.1 for building these infrastructures is the following [1]:

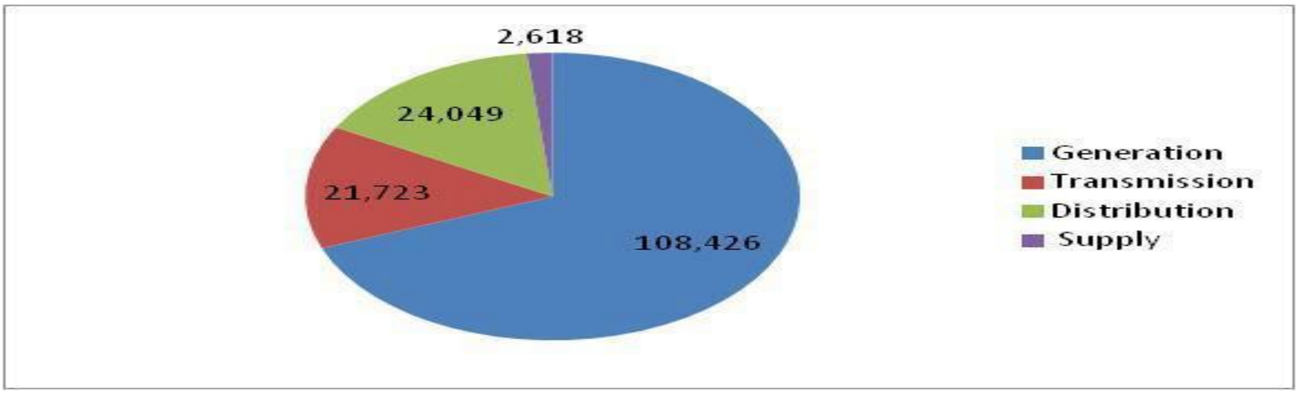


Figure 3-1 cost allocation US$M in 2016 money

System Overview

The total circuit lengths of transmission and sub-transmission lines on the existing system are shown in Table 3-1. EEP plans to phase out 45 kV in favor of 66 kV and also to replace some 66 kV lines with 132 kV. A map of the existing system and the planned transmission projects up to 2016 is shown in Figure 3-2 [28].

Table 3-1Transmission and sub transmission lines on the existing system [1]

No.	Voltage level (kV)	Single circuit	Double circuit	Total
1	400 kV Transmission Line	621	63	684
2	230 kV Transmission Line	3,376	1,607	4,983
3	132 kV Transmission Line	4,509	133	4,641
4	66 kV Transmission Line	1,902		1,902
5	45 kV Transmission Line	243	9	252
TOTAL		10,650	1,811	**12,461**

Reactive compensation is installed at various locations across the network on the system and includes shunt capacitors with a total capacity of approximately 200 MVAr and shunt reactors (both line and bus bar connected), with a total capacity of approximately 700 MVAr. In 2017, the peak generation (including Ethiopia peak demand, losses and exports) was 2078.9 MW.

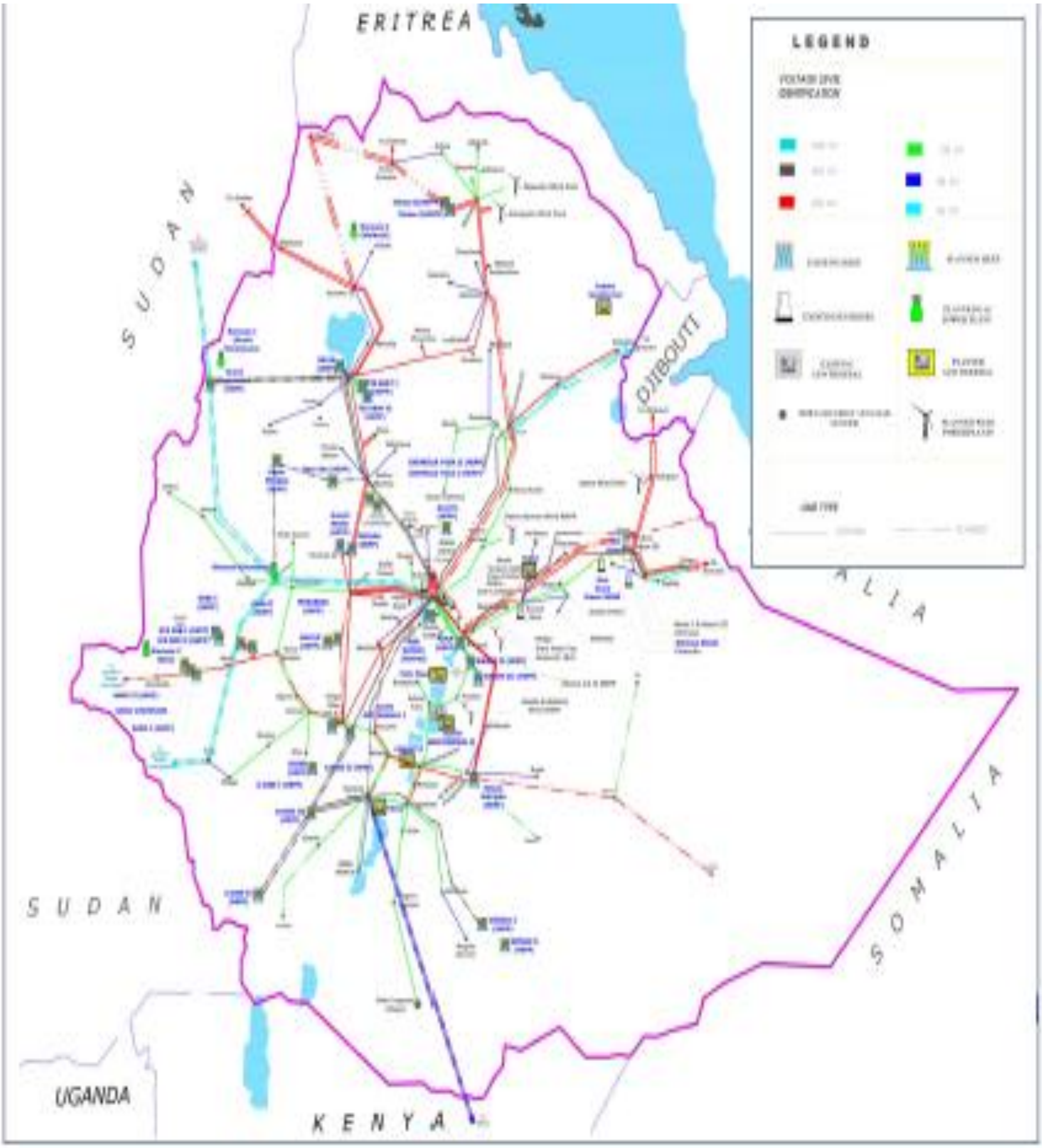


Figure 3-2existing and planned generation and transmission system

400kV Network

The 400-kV network is currently limited to a few transmission lines and substations. These include an interconnection between Gilgel Gibe II/ III power plants and SebetaII to Gelan substation in the south of Addis Ababa and an interconnection between Beles power plant, Bahir Dar, Sululta, Debremarkos and Geberguracha substation to the north of Addis Ababa.

230kV Network

The 230-kV network includes;

- A complete ring around Addis Ababa, including; Sululta, Gefersa, Sebeta kality and Cotobie II to Legetafo.
- Interconnections between Addis Ababa and power plants to the south east including Koka and Melka Wakena.
- Interconnection between Koka and Dire Dawa in the east, with interconnected to Djibouti.
- North-western corridor, including interconnection with Finchaa, Debre Markos, Tis-Abay and Beles power plants and interconnected to Sudan via Metema.
- Northern corridor including Combolcha, Alamata, Mekele and Tekeze power plant.
- A 230-kV transmission line between Bahir Dar and Alamata interconnects the north western and northern corridors

132kV, 66kV and 45 kV

The extent of the 132-kV network has been used extensively in the past for transmission, however in many parts of the network, due to extension of the 230-kV system, 132 kV is now effectively used more for sub-transmission along with 66 kV and 45 kV.

3.2 Ethiopian Grid System Modeling Using PSS/E

The model was developed by the Ethiopian Electric Power most closely refined to 2017 peak load.

Professional software package PSS/E (Power System Simulator for Engineering) is developed by Siemens PTI (Power Technologies International)

PSS/E is a comprehensive time-tested tool for performing power flow (including optimal power flow), short circuit, and transient stability simulation (including long term) of power system networks. The program, used by utility engineers and others worldwide for well over three decades, employs the latest numerical algorithms to efficiently solve networks with up to 150,000 buses with no loss of solution accuracy or computer time

The PSS/E-33 program package has a modern, easy-to-use, Microsoft Foundation Class (MFC), graphical user interface (GUI) for power flow as well as dynamic simulation. The GUI contains commands for recording capability which can be used to automate repetitive calculations.

User-switchable choice of five solution methods including Newton-Raphson (full, decoupled, fast decoupled), Gauss-Seidel, and modified Gauss-Seidel.

PSS/E is comprised of the following calculation modules:

- PSS/E Power Flow
- PSS/E Optimal Power Flow (PSS/E OPF)
- PSS/E Balanced or Unbalanced Fault Analysis
- PSS/E Dynamic Simulation

Module is basic PSS/E program module and it is powerful and easy-to use for basic power flow network analysis. Besides analysis tool this module is also used for Data handling, updating, and manipulation

PSS/E is not set up to solve any specific problem; rather, it is set of computational tools that are directed by the user in an interactive manner. By applying these tools in the appropriate sequence, the engineer can handle a wide range of investigations for the planning and operation of electric power systems.

Through the PSS/E interface the following functions and analyses are available:

- Power flow and related network functions
- Optimal power flow
- Open access
- Fault analysis
- Network equivalency
- Dynamic simulation
- One-line diagrams
- Program automation

Additionally, one of the most basic premises of PSS/E is that the engineer can derive the greatest benefit from computational tools by retaining intimate control over their application. IPLAN program language and or Python programs can be used within PSS/E for batch control and automation of the simulation processes

Overview of the PSS/E User Interface

The PSS/E interface supports a variety of interactive facilities including:

- Introduction, modification and deletion of network data using a spreadsheet.
- Creation of networks and one-line diagrams.
- Steady-state analyses (load flow, fault analysis, optimal power flow, etc.).
- Presentation of steady-state analysis results.
- Dynamic simulations (transient, dynamic and long-term stability analysis
- Presentation of Dynamic simulation results.

Once PSS/E opened, the key elements of the user interface are the Tree View, Spreadsheet View, Diagram View and the Output Bar, as pointed out in Figure 2.8

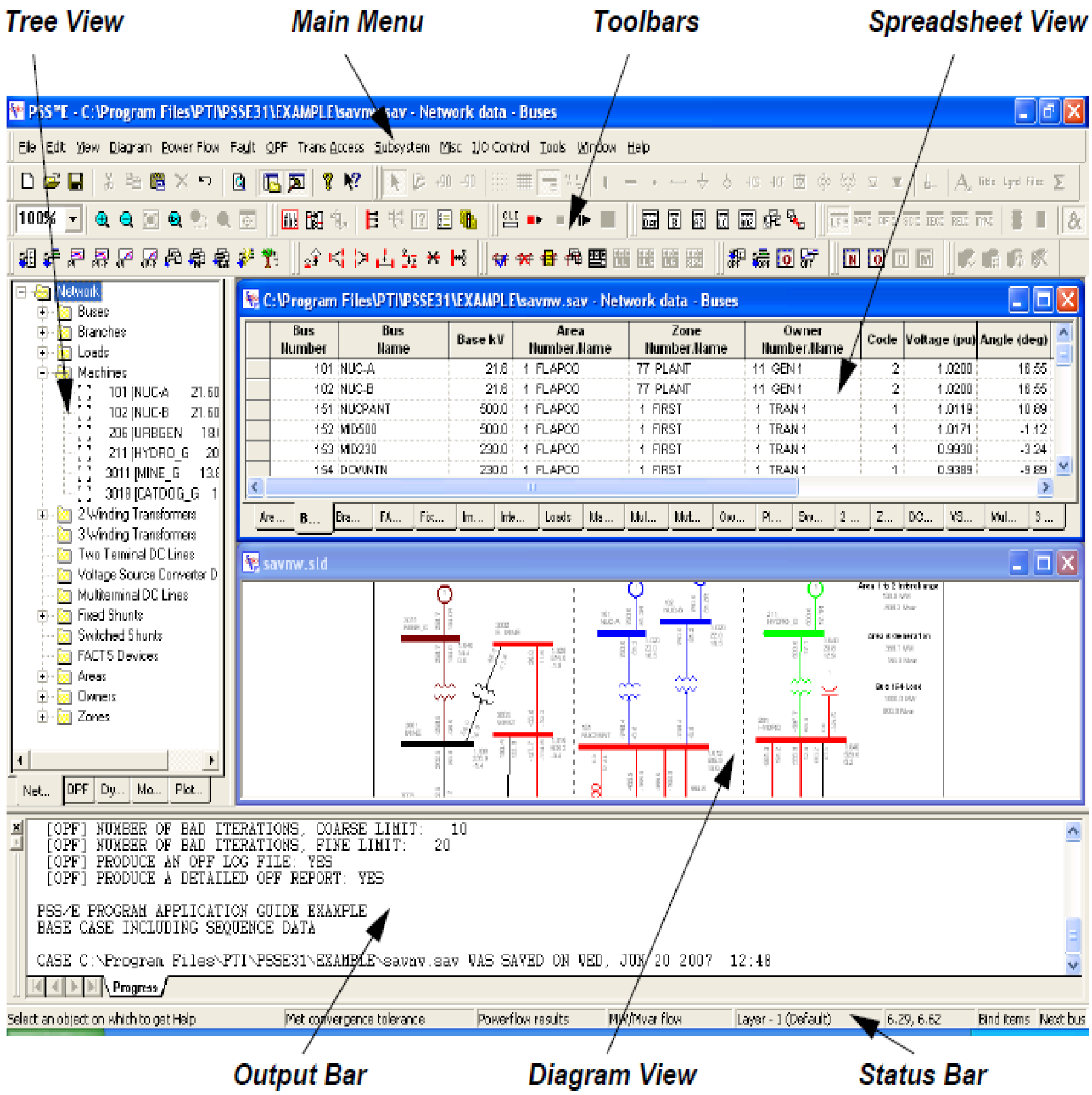


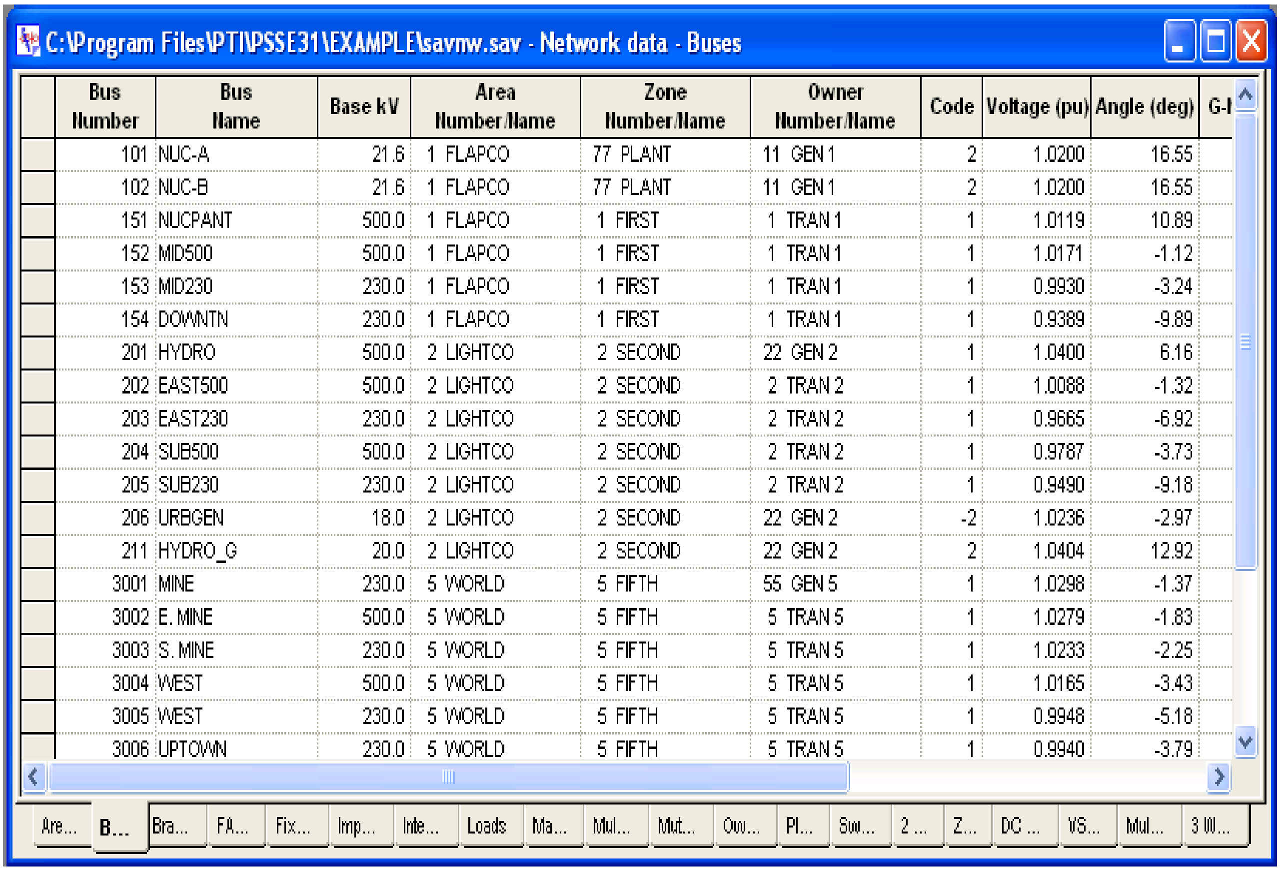
Figure 2 -7Key Elements of the Interface Tree View, Main Menu, Toolbars, Spreadsheet, View Output Bar Diagram, View Status Bar.

Spreadsheet View

All network data components (e.g., buses, lines, loads) are represented within worksheet style tabs on the spreadsheet. The spreadsheet, or workbook, is synchronized with the bus subsystem selector so that only a subset of the data may be viewed at any time. New network elements may be entered or modified directly in the appropriate worksheet, or existing ones deleted. In the Spreadsheet View, standard Windows commands such as copy and paste actions are supported.

Sorting and filtering capabilities are provided to increase usability, especially with large systems. At program startup the Spreadsheet View is not shown. It will appear when a raw data or saved case file is opened. The Spreadsheet View is the default view for the interface and remains open once it is populated. It can be minimized, but if closed will remove the current network from PSS/EE.

In Figure 2.9, the Bus tab has been selected and the spreadsheet reflects the bus data records within the working case. Other data items may be viewed by clicking on the other tabs located at the bottom of the spreadsheet view.


C:\Program Files\PTI\PSSE31\EXAMPLE\savnw.sav - Network data - Buses

Bus Number	Bus Name	Base kV	Area Number/Name	Zone Number/Name	Owner Number/Name	Code	Voltage (pu)	Angle (deg)	G-I
101	NUC-A	21.6	1 FLAPCO	77 PLANT	11 GEN 1	2	1.0200	16.55	
102	NUC-B	21.6	1 FLAPCO	77 PLANT	11 GEN 1	2	1.0200	16.55	
151	NUCPANT	500.0	1 FLAPCO	1 FIRST	1 TRAN 1	1	1.0119	10.89	
152	MID500	500.0	1 FLAPCO	1 FIRST	1 TRAN 1	1	1.0171	-1.12	
153	MID230	230.0	1 FLAPCO	1 FIRST	1 TRAN 1	1	0.9930	-3.24	
154	DOWNTN	230.0	1 FLAPCO	1 FIRST	1 TRAN 1	1	0.9389	-9.89	
201	HYDRO	500.0	2 LIGHTCO	2 SECOND	22 GEN 2	1	1.0400	6.16	
202	EAST500	500.0	2 LIGHTCO	2 SECOND	2 TRAN 2	1	1.0088	-1.32	
203	EAST230	230.0	2 LIGHTCO	2 SECOND	2 TRAN 2	1	0.9665	-6.92	
204	SUB500	500.0	2 LIGHTCO	2 SECOND	2 TRAN 2	1	0.9787	-3.73	
205	SUB230	230.0	2 LIGHTCO	2 SECOND	2 TRAN 2	1	0.9490	-9.18	
206	URBGEN	18.0	2 LIGHTCO	2 SECOND	22 GEN 2	-2	1.0236	-2.97	
211	HYDRO_G	20.0	2 LIGHTCO	2 SECOND	22 GEN 2	2	1.0404	12.92	
3001	MINE	230.0	5 WORLD	5 FIFTH	55 GEN 5	1	1.0298	-1.37	
3002	E. MINE	500.0	5 WORLD	5 FIFTH	5 TRAN 5	1	1.0279	-1.83	
3003	S. MINE	230.0	5 WORLD	5 FIFTH	5 TRAN 5	1	1.0233	-2.25	
3004	WEST	500.0	5 WORLD	5 FIFTH	5 TRAN 5	1	1.0165	-3.43	
3005	WEST	230.0	5 WORLD	5 FIFTH	5 TRAN 5	1	0.9948	-5.18	
3006	UPTOWN	230.0	5 WORLD	5 FIFTH	5 TRAN 5	1	0.9940	-3.79	

Figure 2- 8 Overview of the Spreadsheet View

Tree View

The Tree View provides a hierarchical, expandable and collapsible list view of the network, OPF, dynamics, model, and plot data in the system (as shown in Figure 2.10).

It is synchronized with the bus subsystem selector to enable the user to reduce the amount of data presented at any one time. The Tree View is also synchronized with the Spreadsheet and Diagram Views, reflecting their current content.

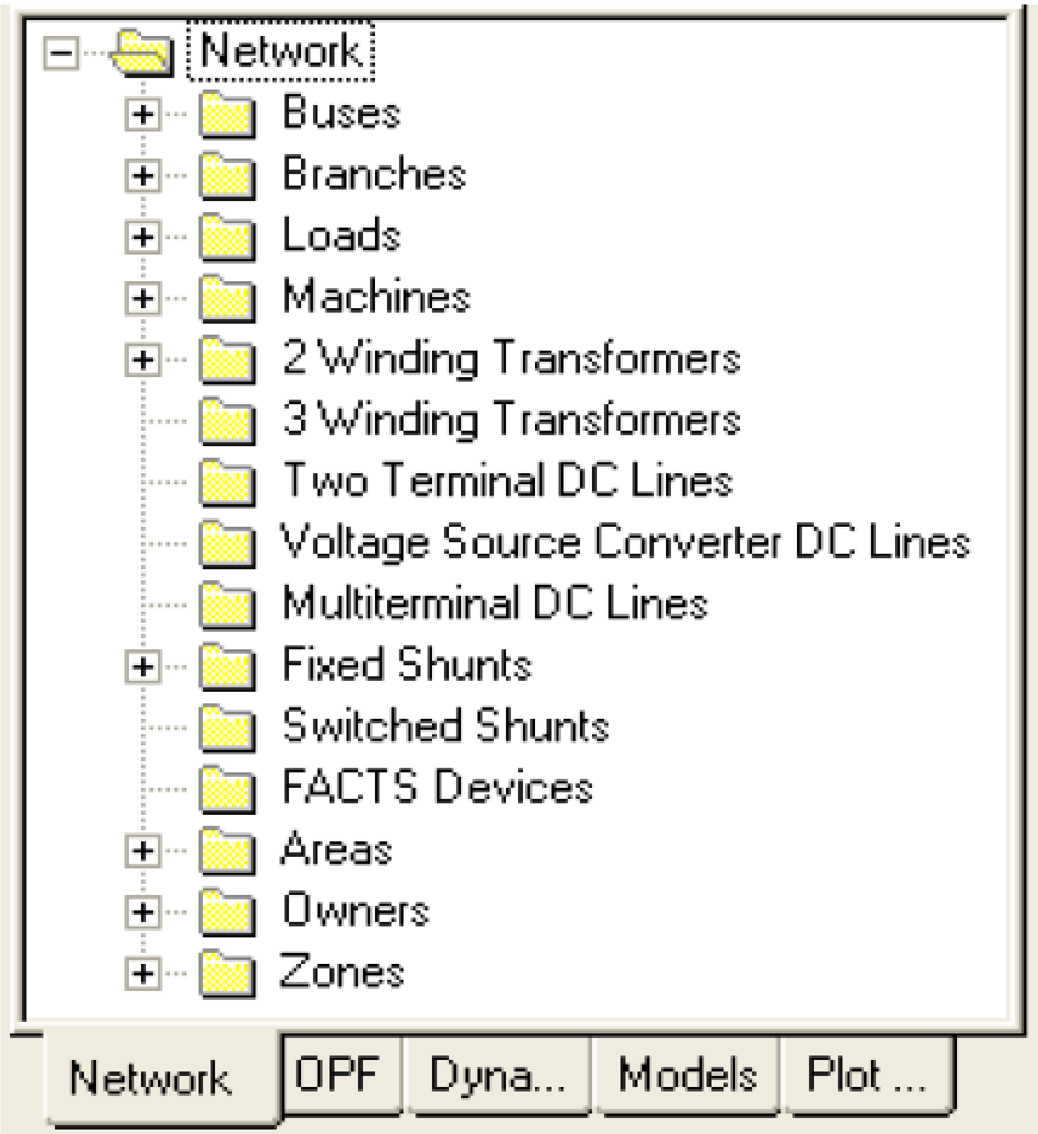


Figure 2 -9 Tree View (expandable form of network components)

Diagram View

The Diagram View is used to create, expand and display one-line diagrams of the electrical system (as shown in Figure 2.11). As new elements are added to the diagram, the Spreadsheet and Tree Views are automatically updated to reflect the addition

Additional diagram capabilities include the ability to view power flow, short-circuit analysis, reliability and dynamic simulation results. The Diagram View is not automatically opened. It is initiated by opening an existing one-line drawing file, or by starting a new diagram window.

The Diagram View can directly import old PSS/E DRAW files, which can then be saved to the new diagram Slider (SLD) format.

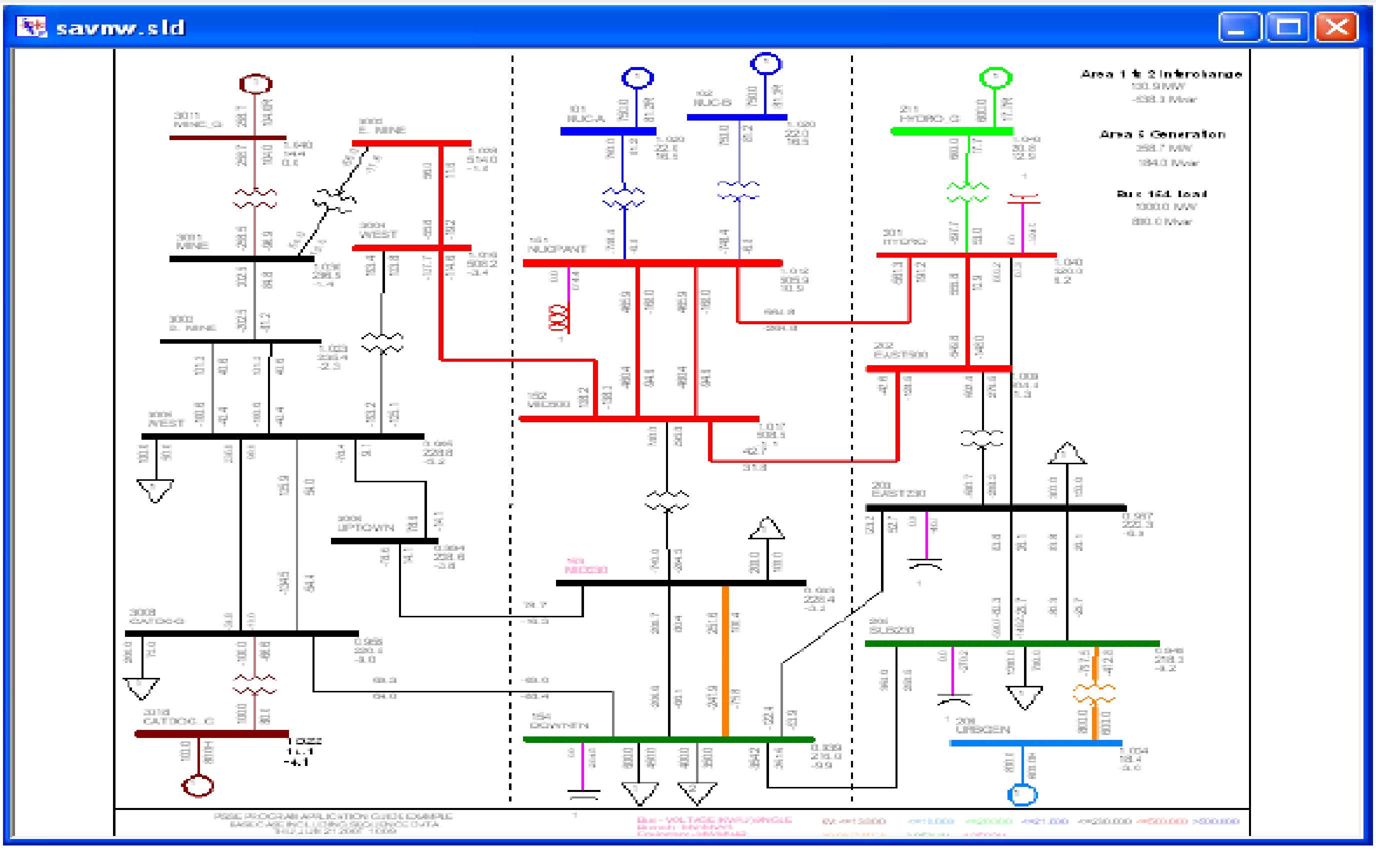


Figure 2- 10 Overview of Diagram View of a sample system

Given an existing PSS/E case, a one-line diagram may easily be built or expanded, bus by bus. This is accomplished by activating a Diagram View, right-clicking on an existing bus within the diagram or tree view and selecting Grow. All items connected to the selected bus are automatically drawn on the diagram. Simple mouse operations may then be used to rearrange elements on the diagram.

3.3 Model in PSS/E

EEP provided a PSS/E network model, which formed the basis of the analysis. The model was refined to more closely represent the network in 2017 peak load and the generation is 2078.9 MW (including the peak load, exports and the loss).The peak 2017 data's are line R in (pu), line X in (pu), charging B in (pu), ratings of A, B, and C phases in MVA and line lengths in km are listed in **Appendix B.**

Performance Evaluation of Existing Transmission System

Network analysis was conducted on the existing Ethiopian transmission system, to identify constraints and to develop a model which would provide the basis for the transmission expansion plan. In this section of the report we discuss the findings of the studies on the existing system and identify reinforcements required to support peak demand conditions across the network.

A summary of the assessment results is shown that 285 lines are monitored and during contingency analysis 12 lines are tripped, and a number of loads sheds done for corrective action are 12 lines with further details including summary of contingency analysis study results provided in **Appendix A.**

Load Flow Studies

The load flow plots may be found in **Appendix A**. Under maximum load, intact network conditions, a number of transmission line and transformer overloads, VAR limits of the existing power generating stations, and peak load flow were found, and are listed in **Appendix C**.

In order to maximize a peak load flow, it was necessary to significantly reduce the overloaded lines and fully utilize the unused capacity of the 230kV and 400kV lines.

Numerous transformer overloads were found, mostly in the Addis Ababa region and these are listed in **Appendix C**. These will be addressed through replacement of existing transformers as required and through transfer of load to new substations in certain cases. Voltages below and above the planning limits were found on the bus bars listed in **Appendix D**.

Contingency Analysis

The transmission system currently carries very little redundancy and therefore is generally unable to withstand line or transformer outages without loss of supply to part of the network. Many of the substations are supplied over single radial 132 kV and 230kV circuits and will of course lose supply completely on loss of that circuit. Even if two parallel lines exists on some parts of the area due to unbalanced transmission lines exists in the network, some lines are overloaded first and have an additional impact for cascade tripping. As the network is developed, it is assumed that supply to these substations will be improved such that N-1 security is achieved. Investigation of overloaded lines has to be carried due to sudden outages of units, lines and transformers and a remedial action has to be taken like alleviating overloaded lines by balancing the transmission lines and push more power from overloaded lines to those lines that have unused capacity. The existing system contingency analysis has attached on **Appendix A.**

3.4 Investigation of Partial Blackout of the System as of 2017

The partial system blackout occurred at around 06:11on 04thNov 2017 (SCADA time). Immediately prior to the incident the system conditions were as follows:

Table 3- 2 Generation Dispatch

No.	Power Station	Number Units on the System Available	Total Generation MW
1	Beles HPP	1,3 and 4	330
2	Gilgele Gibe II HPP	2,3 and 4	325
3	Tekeze HPP	1 and 3	142
4	Fincha HPP	All	120
5	Gigle Gibe I HPP	All	140
6	Melkewakena HPP	1	55
7	Koka HPP	1	15
8	Awash II	2	25

9	Awash III	2	13
10	Adama Wind II	All	5.66
11	Adama Wind I	All	1.81
12	Gilegle Gibe III	1,4,5 and 6	613.55
13	Ashegoda wind	All	0.1
Total Generation			1786.12

Table 3-3 Interconnection Transfer

Interconnection	Transfer MW
Sudan	157
Djibouti	54.66

Preliminary Grid Disturbance Report:

- Type of Grid disturbance is type C (More than 80% of the grid affected)
- Affected Area: Except North West region all areas were affected

- Plant and/or Equipment directly involved: Except Beles power plant and North West region all power Plants and Substations were involved.

  Immediately prior to the grid affected the following circuit was out of service;
- Bahir Dar – Mota 230kV by Earth fault

The sequence of events provided by the Transmission System Operator

Table 3-4 Sequence of Events

Time	Circuit /Generator Tripping	Effect
06:13	Bahir dar - Alamata -230 kV line	Over current
06:14	Beles HPP	Reverse Power
06:15	MelkaWakena HPP	Over current/Overloaded
06:15	Koka HPP	Over current
06:15	Awash III HPP	Over Current
06:15	Awash II HPP	Over current
06:17	All Tekeze Generation	Over Frequency Trip
06:17	W/sodoll – Gelan 400kv line	Thought to be the cause of the blackout

06:18	GG III	Over Frequency Trip
06:18	Adama wind II	Voltage loss
06:20	Adama Wind I	Voltage loss
06:51	GGII HPP	Over Frequency Trip
06:51	Gelan – Kaliti I 230kv linr I and line ll	Unknown
06:52	GGI HPP	Over Frequency Trip
06:54	Ashegoda wind	Loss of Voltage
06:56	Fincha HPP	Over Frequency Trip

The existing system assessment showed that:

- Tripping of Bahir dar - Mota 230kv line also caused to trip Bahir dar – Alamata 230kv line with over current which isolate Beles from the grid at the same time
- The grid is weak does not fulfill the N-1 criteria during contingencies [1].
- There are overloaded lines and transformers during peak time certain times of a day and during contingencies.
- Poor protection coordination systems.
- A review has to be carried out under frequency load shedding.

- The grid peak demand serves approximately 2079MW (60% in Addis Ababa) [1]
- Mostly radial lines with limited interconnection.
- 230 kV and 132 kV are the most extensively used in the network
- 230 kV interconnectors to Djibouti and Sudan with limited capacity

Generally speaking, when line is overloaded EEP operators follow the traditional way of shedding loads automatically and manually to save the system from contingencies and blackout and partial blackout following cascade tripping of the system parameters.

EEP solving the overloaded lines problems by constructing new transmission lines instead of using FACTS devise to alleviate overloads and delay investment costs.

On this study uses DSRs on overloaded lines due to peak load at certain time of the day by identifying after load flow analysis. Distributed series reactors can be used to increase the capacity of a transmission system by moving flow from heavily loaded lines to lines that are in parallel and which have unused capacity.

3.5 DSRs Placement to Improve the Performance of Transmission System

The line overloads were all in shown one the Table 3.5 peak load flow of 2017 and it shows loading above from its ratings.

Table 3-5loading above its ratings

	X--------- FROM BUS ----------X X---------- TO BUS -----------X							
BUS#	X----NAME----X BASKV	AREA	BUS#	X-- NAME --X BASKV	AREA	CKT	LOADING IN MVA	RATING SET A (MVA)
112001	ADDIS CENTER 132	12	112005	KALITI1 132	12	1	85.6	82
112009	MEKANISA 132	12	114002	SEBATA -I 132	14	1	95	82
113002	ALABA 132	13	113009	SHASHEMENE 132	13	1	106.5	89
113002	ALABA 132	13	113012	W SODO-II 132	13	1	112	89

113003	AWASA 132	13	113009	SHASHEMENE 132	13	1	88.1	82

Here have seen clearly on Figure 3.3 during peak time of 2017 the system with a generation of 2079 MW (including peak loads, exports and loss) are shown here:

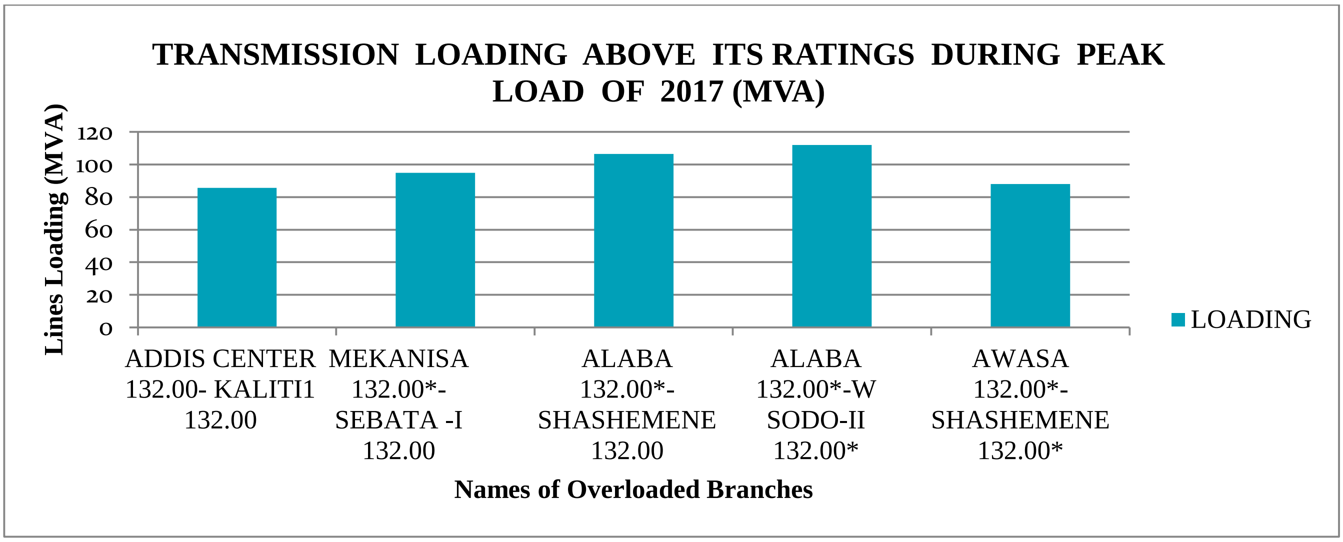


Figure 3- 3 loading above its ratings

Following DSRs operating flow chart as showed in Fig 1.1 the maximum peak load overloading lines more than its ratings are listed above. Addis Center – Kality 132kV line is a radial line and omitted putting DSRs on it. Mekanisa- Sebta I 132kV line has connected branch only Sebta I- Gefersa 230 kV line and not include the highest voltage level of the system (400kV lines). Alaba –Shashemene and Awasa – Shashemene have nodes of connecting branches of 132kV transmission lines and have same impedance and overloading capability. The only line, Alaba –Wolyta SodoII 132kV, has the highest overloading among them. In addition to this, the node is connected with the highest voltage level of the system 400kV Wolyta Sodo II-Gilgle Gibe II and which is connected to the main load center of the capital city (which is 60% of the generation) [1]. For further reference please see the network diagram attached on **Appendix D**.

The flow shown on the Wolyta Sodo II node bus connected branches in MW and MVar, the bus voltage in KV and PU and the angle in degree. The node view shown in Fig 3-4

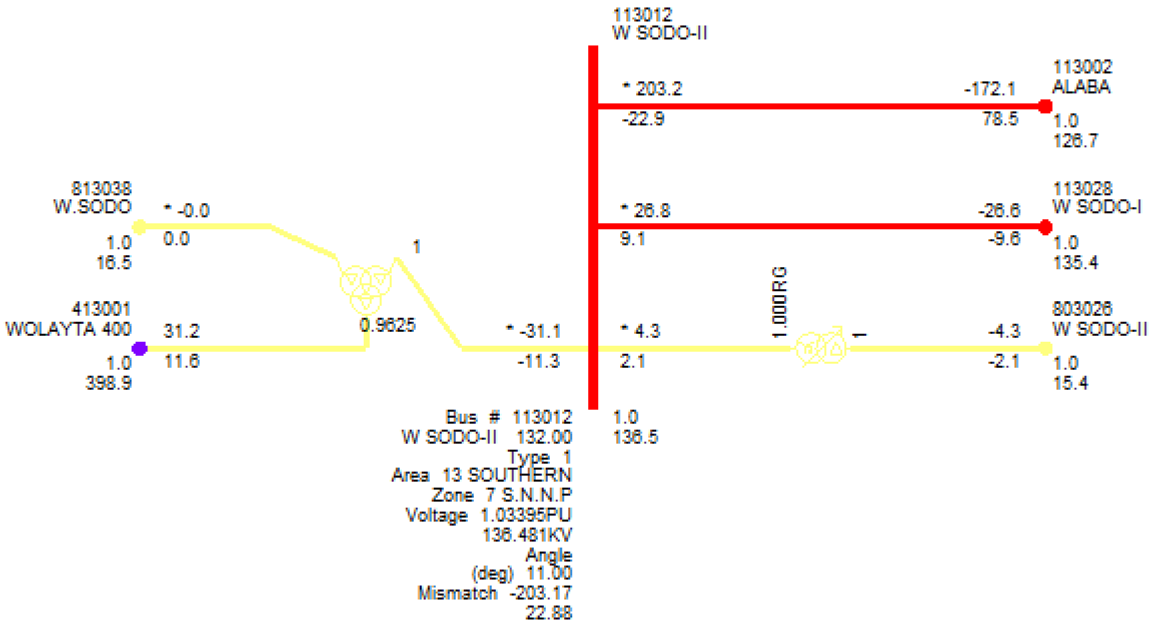


Figure 3- 4 Node View of Wolyta Sodo II

The DSR technology is based on increasing the impedance of a line, thereby pushing power flow from the line to other parallel paths. When a transmission line approaches its thermal rating, DSR modules may be activated to increase line impedance. This increases the power flow through parallel lines that may still have remaining capacity, more fully utilizing the capacity of the transmission system. The algorithm used here to place and operate DSRs is showed in Figure 1.1

The DSRs has placed on the overloaded 132kV Alaba –Wolyta Sodo II line, has a thermal capacity of the line 809A.

For the 10KVA rated DSRs, the required impedance for the module will be:

$$R = S/I^2 \quad (3.1)$$

$$R = \frac{10{,}000}{809^2}$$

R =0.01528Ω

The DSR modules used for this study have an inductance of one module 0.05 mH/module (0.01528 Ω). The DSR Modules on transmission line has been deployed having its reactance value 20%, 30% and 50% of the Alaba- Wolyta Sodo II line. A dummy bus (WS2-ALA-DUM) inserted between Wolyta Sodo II and Alaba 132KV line. A dummy bus (WS2-ALA-DUM1) having its reactance value 20% of overloaded line is inserted between Wolyta Sodo II and WS2-ALA-DUM.A dummy bus (WS2-ALA-DUM2) having its reactance value 30% of overloaded line inserted between Wolyta Sodo II and WS2-ALA-DUM and a dummy bus (WS2-ALA-DUM3) having its reactance value 50% of overloaded line is inserted between Wolyta Sodo II and WS2-ALA-DUM. The placement of DSRs on the line shown on Figure 3.5 here:

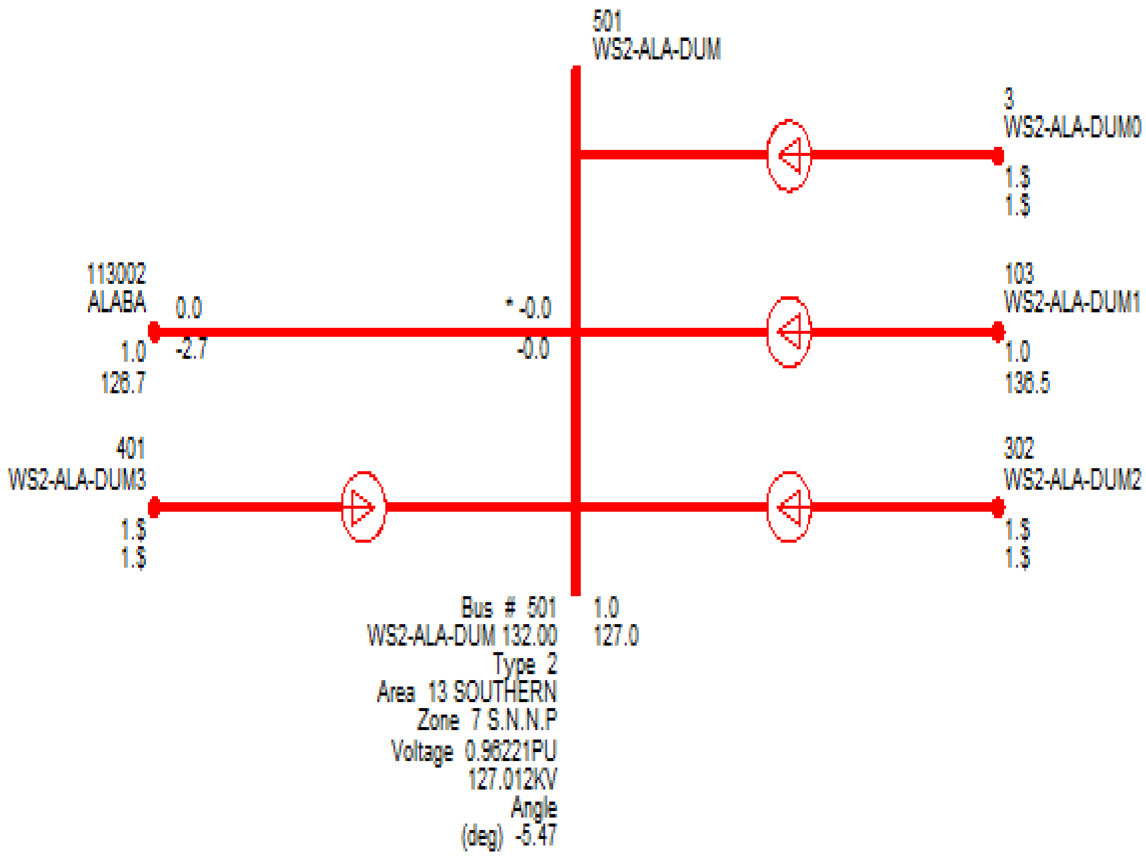


Figure 3-5Node View of Wolyta Sodo II for Placement of DSRS

Wolyta Sodo II-Alaba 132kV line parameters shown on the following Table 3.6

Table 3- 6 Line parameters

Operating voltage(kV)	Loading Capacity(MVA)	Length of line (km)	R(ohm)	X(ohm)
132	89	61.81	13.887224	26.137918

As the overall control objective is to keep the lines from thermal overload, the control strategy is seen to be very simple. The control algorithm is given by the line a relation between line current and injected inductance, as shown in Figure 3.6 [7] and explained by equation (3.2). The same controller, but with different set points is located on each module.

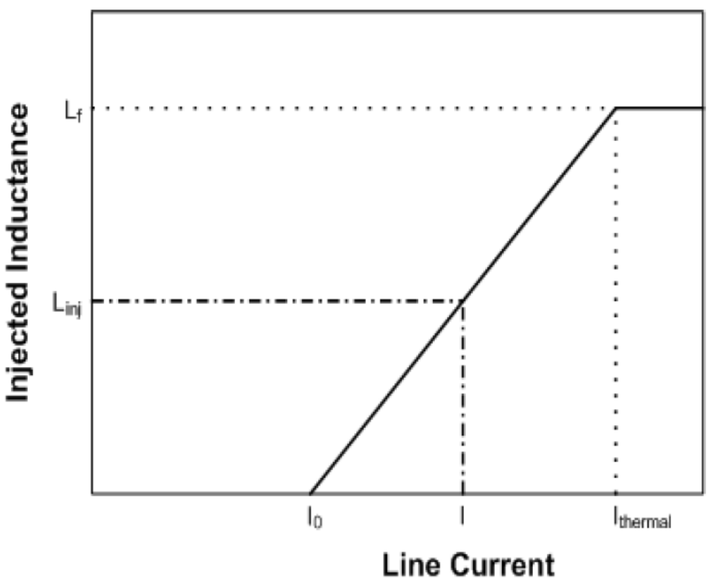


Figure 3- 6 Relation between injected inductance and line current

$$L_{inj} = L_f \frac{(I - I_0)}{(I_{thermal} - I_0)} \quad (3.2)$$

Here L_{inj} is the required injection; L_f is the final value of inductance with all the DSR modules on the line active, I_0 is the threshold value of current, I is the line current, and $I_{thermal}$ is the thermal limit beyond which there is no injection.

The range for inductance injection (L_f) is 100% of the line reactance and it was determined by system simulation to assess worst case requirements of thermal overload.

CHAPTER 4

PERFORMANCE EVALUATION OF THE TRANSMISSION SYSTEM WITH DSRs AND COST BENEFIT ANALYSIS

4.1 Introduction

This chapter begins by describing the selection criteria for connected branches of Wolyta Sodo II- Alaba 132kV transmission lines. The aim is pushing more power to the high voltage level which is the 400kV and the 230 kV transmission lines connected to the node of overloaded line. Based on the structure of the Ethiopian grid network the effect of DSR could see on the nearby lines which is directly or indirectly connected to the overloaded line. The loading of these lines has been taken during the peak load of 2017.The following table 4.1 shows lines selected for analysis

Table 4- 1 Transmission lines selected for analysis

	X--------- FROM BUS ----------X			X---------- TO BUS -----------X							
BUS#	X-- NAME --X	BASKV	AREA	BUS#	X-- NAME --X	BASKV	AREA	CKT	LOADING (MVA)	RATING (MVA)	PERCENT (MVA)
113012	W SODO-II	132	13	113028	W SODO-I	132	13	1	27.6	89	31
413001	WOLAYTA	400	13	415001	GI GIBE-2	400	15	1	409.4	1973	20.7
402002	GELAN	400	12	413001	WOLAYTA	400	13	1	527.5	1973	26.7
402002	GELAN	400	12	414001	SEBETA-2	400	14	1	222.1	1973	11.3
212001	KALITI1	230	12	212005	GELAN	230	12	1	49.3	331	14.9
112005	KALITI1	132	12	112011	GELAN	132	12	1	110.4	115	96
211001	KOKA	230	11	212005	GELAN	230	12	1	118.5	331	35.8
402002	GELAN	400	12	414001	SEBETA-2	400	14	1	222.1	1973	11.3
214001	SEBATA-1	230	14	214002	SEBETA-2	230	14	1	236.5	280	84.5
108003	GEFERSA	132	8	114002	SEBATA -I	132	14	1	19.5	82	23.8
112009	MEKANISA	132	12	114002	SEBATA -I	132	14	1	95	82	115.8
113002	ALABA	132	13	113008	HOSAINA	132	13	1	11.4	89	12.8
213005	HOSAINA	230	13	214003	WOLKITE	230	14	1	23.5	402	5.9
213004	ALABA	230	13	213005	HOSAINA	230	13	1	30.6	402	7.6
113008	HOSAINA	132	13	115005	G.GIBE NEW	132	15	1	24	89	27

The load flow simulations of the existing transmission system 400kV, 230kV and 132KV voltage levels without DSRs and with DSR are conducted. Analysis of the simulation result is also presented in item 4.4 on result analysis in regards to the capacity improvements of the lines. The load flow analysis is carried out using PSS/E software [13].

4.2 Simulation Studies of the Transmission System without DSR

The loads are considered the peak load of 2017, which is the generation of 2078.9 MW [28]. This operating point determines the maximum amount of power that can be transferred over the transmission lines without DSRs. The loading and ratings of the transmission lines capacity without DSRs connected to 132kV Wolyta Sodo II bus is shown in table 4.2 and Figure 4.1. It can be seen that the 132-kV line is about to reach its maximum capacity, while there is capacity still available on 230kv lines. On the other hand, shows that all the lines of the 400-kV line have available transmission capacity.

Table 4-2Branches loading, Ratings and percentage without DSR

BRANCHES	WIHOUT DSR		
NAMES	LOADING(MVA	RATING(MVA)	PERCENTAGE (%)
W SODO-II 132kV-W SODO-I 132kV	27.6	89	31
WOLAYTA 400kV-GI GIBE-2 400kV	409.4	1973	20.7
GELAN 400kV-WOLAYTA 400kV	527.5	1973	26.7
GELAN 400kV-SEBETA-2 400kV	222.1	1973	11.3
KALITI1 230kV-GELAN 230kV	49.3	331	14.9
KALITI1 132kV-GELAN 132kV	110.4	115	96
KOKA 230kV-GELAN 230kV	118.5	331	35.8
GELAN 400kV-SEBETA-2 400kV	222.1	1973	11.3
SEBETA 1-230kV-SEBETA 2-230kV	236.5	280	84.5
GEFERSA 132kV-SEBETA 1-132kV	19.5	82	23.8
MEKANISA 132kV-SEBETA1-132kV	95	82	115.8
ALABA 132kV-HOSAINA 132kV	11.4	89	12.8
HOSAINA 230kV-WOLKITE 230kV	23.5	402	5.9
ALABA 230kV-HOSAINA230kV	30.6	402	7.6
HOSAINA 132kV-G.GIBE NEW 132kV	24	89	27

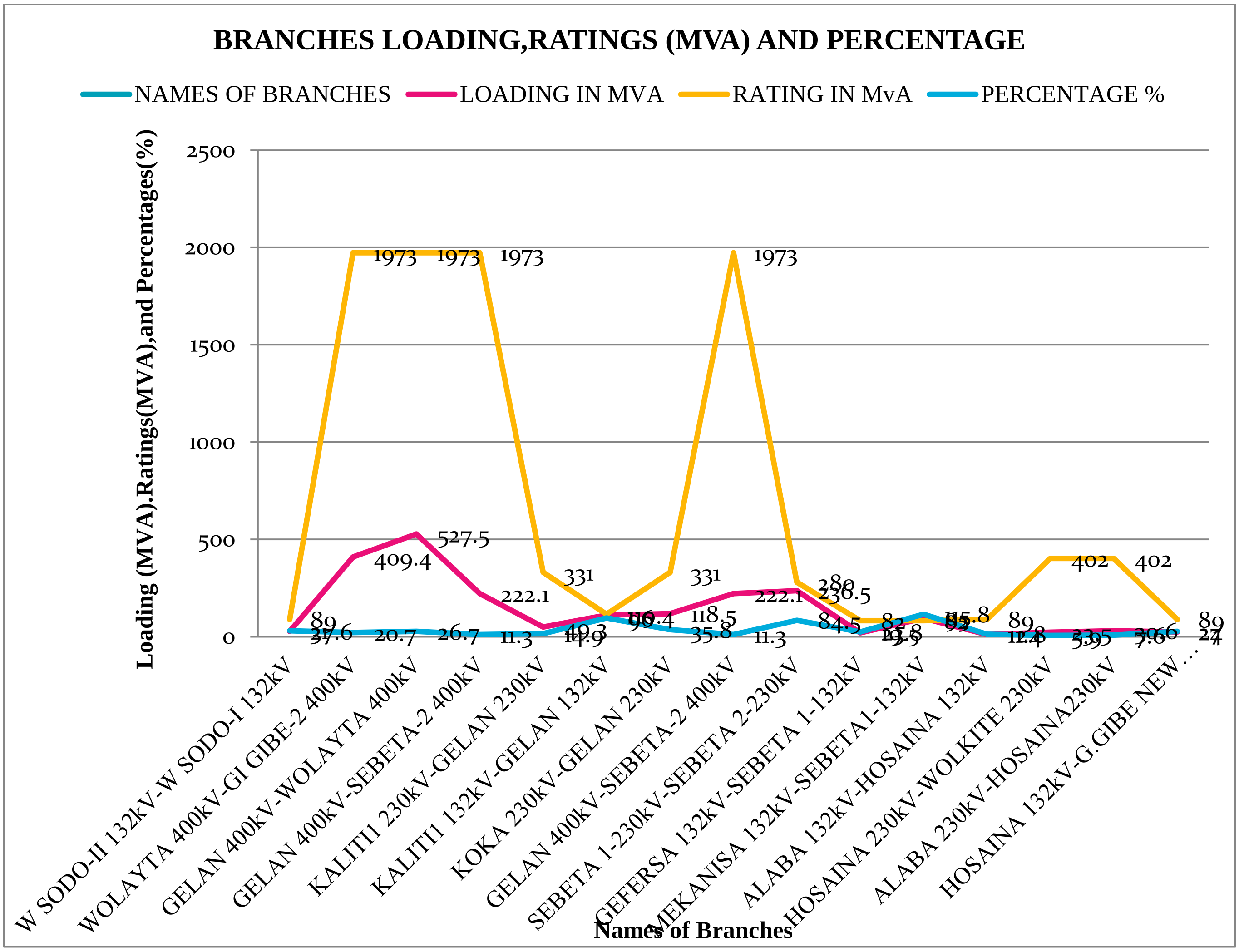


Figure 4- 1 Line graphs for branches loading, ratings and percentage

The nearby branches connected to the overloaded line, Figure 4-1 shows the 400KV lines have average 82.5% unused capacity without DSRs. The 230KV lines have average 70.3% unused capacity without DSRs and the 132KV lines have an average unused capacity is 49% without DSRs.

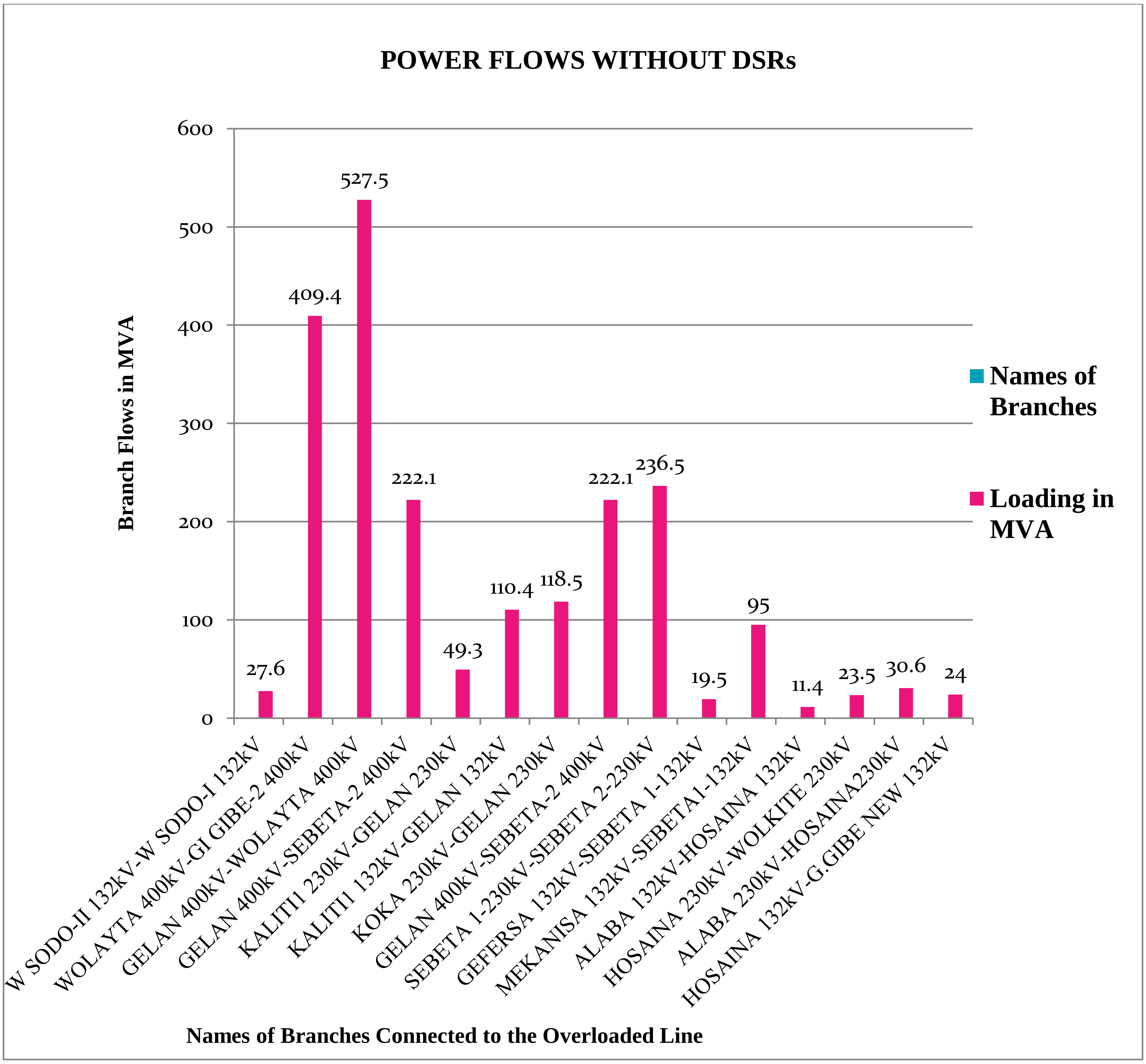


Figure 4-2 Power flows on Branches without using DSRs

4.3 Simulation Studies of the Transmission System with DSRs

Placement of DSRs having its reactance value 20%, 30% and 50% of 132kV Alaba to Wolyta Sodo II line are operated on the three phases of the 132-kV line. As can be seen from Tables 4.3, 4.4 and 4.5, by increasing the reactance of the overloaded line by 20% (adding 342 DSRs rated at 10kVA, 0.01528Ω), by 30% (adding 513DSRs rated at 10kVA, 0.01528Ω) and by 50% (adding 856DSRs rated at 10kVA, 0.01528Ω) across the three phases, the overload on the 132-kV Alaba - Wolyta Sodo II line can be removed and power flow is transferred to the parallel branches of 400kV and 230 kV line.

Table 4-3 Placement of DSR Having its Reactance Value 20% of 132kVAlaba – Wolyta Sodo II line

	X--------- FROM BUS ----------X			X---------- TO BUS -----------X							
BUS#	X-- NAME --X	BASKV	AREA	BUS#	X-- NAME --X	BASKV	AREA	CKT	LOADING (MVA)	RATING(MVA)	PERCENT(%)
113012	W SODO-II	132	13	113028	W SODO-I	132	13	1	27.6	89	31
413001	WOLAYTA	400	13	415001	GI GIBE-2	400	15	1	484.9	1973	24.6
402002	GELAN	400	12	413001	WOLAYTA	400	13	1	566.3	1973	28.7
402002	GELAN	400	12	414001	SEBETA-2	400	14	1	248.4	1973	12.6
212001	KALITI1	230	12	212005	GELAN	230	12	1	44.7	331	13.5
112005	KALITI1	132	12	112011	GELAN	132	12	1	115	115	100
211001	KOKA	230	11	212005	GELAN	230	12	1	130.2	331	39.3
402002	GELAN	400	12	414001	SEBETA-2	400	14	1	248.4	1973	12.6
214001	SEBATA-1	230	14	214002	SEBETA-2	230	14	1	251.2	280	89.7
108003	GEFERSA	132	8	114002	SEBATA -I	132	14	1	18.9	82	23
112009	MEKANISA	132	12	114002	SEBATA -I	132	14	1	96.7	82	117.9
113002	ALABA	132	13	113008	HOSAINA	132	13	1	37.3	89	42
213005	HOSAINA	230	13	214003	WOLKITE	230	14	1	68.2	402	17
213004	ALABA	230	13	213005	HOSAINA	230	13	1	69.7	402	17.3
113008	HOSAINA	132	13	115005	G.GIBE NEW	132	15	1	48.1	89	54

Table 4- 4 Placement of DSR having its Reactance Value 30% of 132kVAlaba – Wolyta Sodo II line

	X--------- FROM BUS ----------X			X---------- TO BUS -----------X							
BUS#	X-- NAME --X	BASKV	AREA	BUS#	X-- NAME --X	BASKV	AREA	CKT	LOADING (MVA)	RATING(MVA)	PERCENT(%)
113012	W SODO-II	132	13	113028	W SODO-I	132	13	1	27.6	89	31
413001	WOLAYTA	400	13	415001	GI GIBE-2	400	15	1	485.5	1973	24.6
402002	GELAN	400	12	413001	WOLAYTA	400	13	1	565.7	1973	28.7
402002	GELAN	400	12	414001	SEBETA-2	400	14	1	248.4	1973	12.6
212001	KALITI1	230	12	212005	GELAN	230	12	1	45.3	331	13.7
112005	KALITI1	132	12	112011	GELAN	132	12	1	115.2	115	100.2
211001	KOKA	230	11	212005	GELAN	230	12	1	130.1	331	39.3
402002	GELAN	400	12	414001	SEBETA-2	400	14	1	248.4	1973	12.6
214001	SEBATA-1	230	14	214002	SEBETA-2	230	14	1	250.6	280	89.5
108003	GEFERSA	132	8	114002	SEBATA -I	132	14	1	23.2	82	28.3
112009	MEKANISA	132	12	114002	SEBATA -I	132	14	1	98	82	119.5
113002	ALABA	132	13	113008	HOSAINA	132	13	1	37.3	89	41.9
213005	HOSAINA	230	13	214003	WOLKITE	230	14	1	68.1	402	16.9
213004	ALABA	230	13	213005	HOSAINA	230	13	1	69.6	402	17.3
113008	HOSAINA	132	13	115005	G.GIBE NEW	132	15	1	48	89	53.9

Table 4- 5 Placement of DSR having its Reactance Value 50% of 132kVAlaba – Wolyta Sodo II line

	X--------- FROM BUS ----------X			X---------- TO BUS -----------X							
BUS#	X-- NAME --X	BASKV	AREA	BUS#	X-- NAME --X	BASKV	AREA	CKT	LOADING (MVA)	RATING(MVA)	PERCENT(%)
113012	W SODO-II	132	13	113028	W SODO-I	132	13	1	27.6	89	31
413001	WOLAYTA	400	13	415001	GI GIBE-2	400	15	1	486.1	1973	24.6
402002	GELAN	400	12	413001	WOLAYTA	400	13	1	565.1	1973	28.6
402002	GELAN	400	12	414001	SEBETA-2	400	14	1	248.4	1973	12.6
212001	KALITI1	230	12	212005	GELAN	230	12	1	45.9	331	13.9
112005	KALITI1	132	12	112011	GELAN	132	12	1	115.4	115	100.4
211001	KOKA	230	11	212005	GELAN	230	12	1	130.1	331	39.3
402002	GELAN	400	12	414001	SEBETA-2	400	14	1	248.4	1973	12.6
214001	SEBATA-1	230	14	214002	SEBETA-2	230	14	1	250.1	280	89.3
108003	GEFERSA	132	8	114002	SEBATA -I	132	14	1	31.9	82	38.9
112009	MEKANISA	132	12	114002	SEBATA -I	132	14	1	99.3	82	121.1
113002	ALABA	132	13	113008	HOSAINA	132	13	1	37.2	89	41.7
213005	HOSAINA	230	13	214003	WOLKITE	230	14	1	68.1	402	16.9
213004	ALABA	230	13	213005	HOSAINA	230	13	1	69.6	402	17.3
113008	HOSAINA	132	13	115005	G.GIBE NEW	132	15	1	47.9	89	53.8

Placement of DSRs having its reactance value 30% and 50% of the overloaded Alaba to Wolyta Sodo II line, the alternative passes which don't require DSRs previously for Kality 1 –Gelan 132kV and Mekanisa -Sebta 1 132kV lines getting a significant overload and requires additional placement of DSR to remove the overload and transfer the excess power to the 400kV and 230 kV line. Placement of DSRs having its reactance value 20 % (342 DSRs rated at 10kVA, 0.01528Ω) of the overloaded Alaba to Wolyta Sodo II line for alleviating the existing transmission line is enhanced the capacity for parallel branches for 400kV, 230kV and 132kV lines and moreover the overloading conditions is improved. The capacity improvement having its reactance value 20% of the overloaded line Alaba to Wolyta Sodo II is shown in the following Figure 4.3

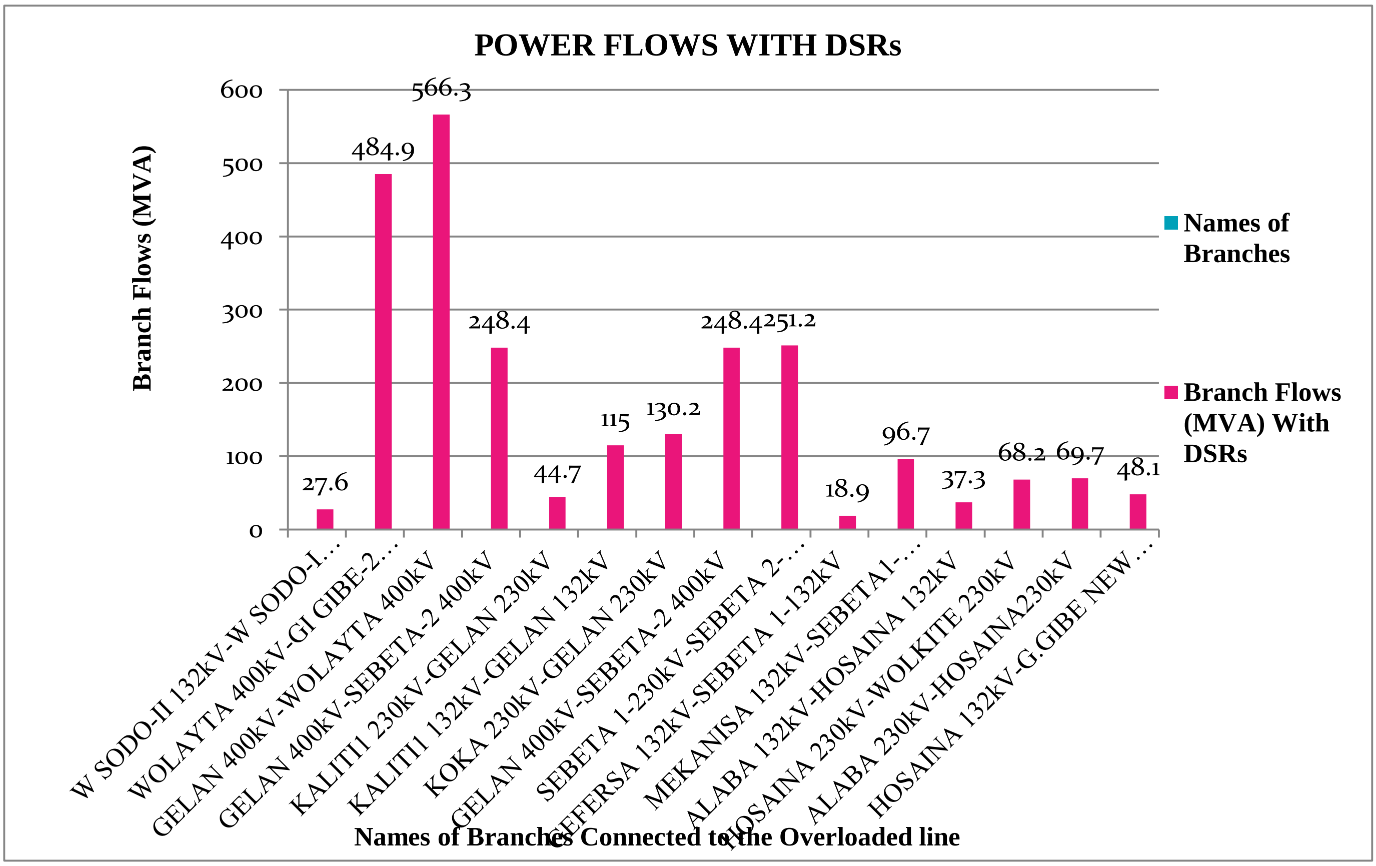


Figure 4-3Power Flow on Branches using DSRs

Calculations for number of DSRs modules to change line reactance by 1%

LINE VOLTAGE	132KV
THERMAL CAPACITY	106.8MVA
CURRENT CARRYING CAPACITY	700A
# OF CONDUCTOR /DIAMETER (CM)	2.54/2.54
REACTANCE IN OHMS / KM	0.42OHMS
REACTIVE VOLTAGE DROP /KM	294V
1% COMPENSATION/ KM	2.94V
DSR KVA/KM-1% COMPENSATION	2.38KVA
TOTAL 10KVA DSRs MODULE /KM/1%COMPENSATION	0.238

Taking the 132 kV Alaba to Wolyta Sodo II overloaded line, it has seen that the reactive voltage drop is 294V/km at rated current corresponding to 0.42 ohms/km).A 1% change in the impedance thus requires an injection of 2.94 V/km, corresponding to a combined DSR rating of 2.38 kVA/km based on three phase injection. A variation of 20% in line impedance would thus need 47.6 kVA or 4.76 (~5) of the 10 kVA DSR modules/km or approximately 2 modules per conductor per km.

4.4 Analysis of Simulation Results

Power Flow

Figs. 4.4and 4.5shows the comparison of power flows without and with DSRs of having its reactance value 20% of Alaba to Wolyta Sodo II transmission line. Power flows over the 132kV, 230 kV and 400kV branches connected to the overloaded line are shown here.

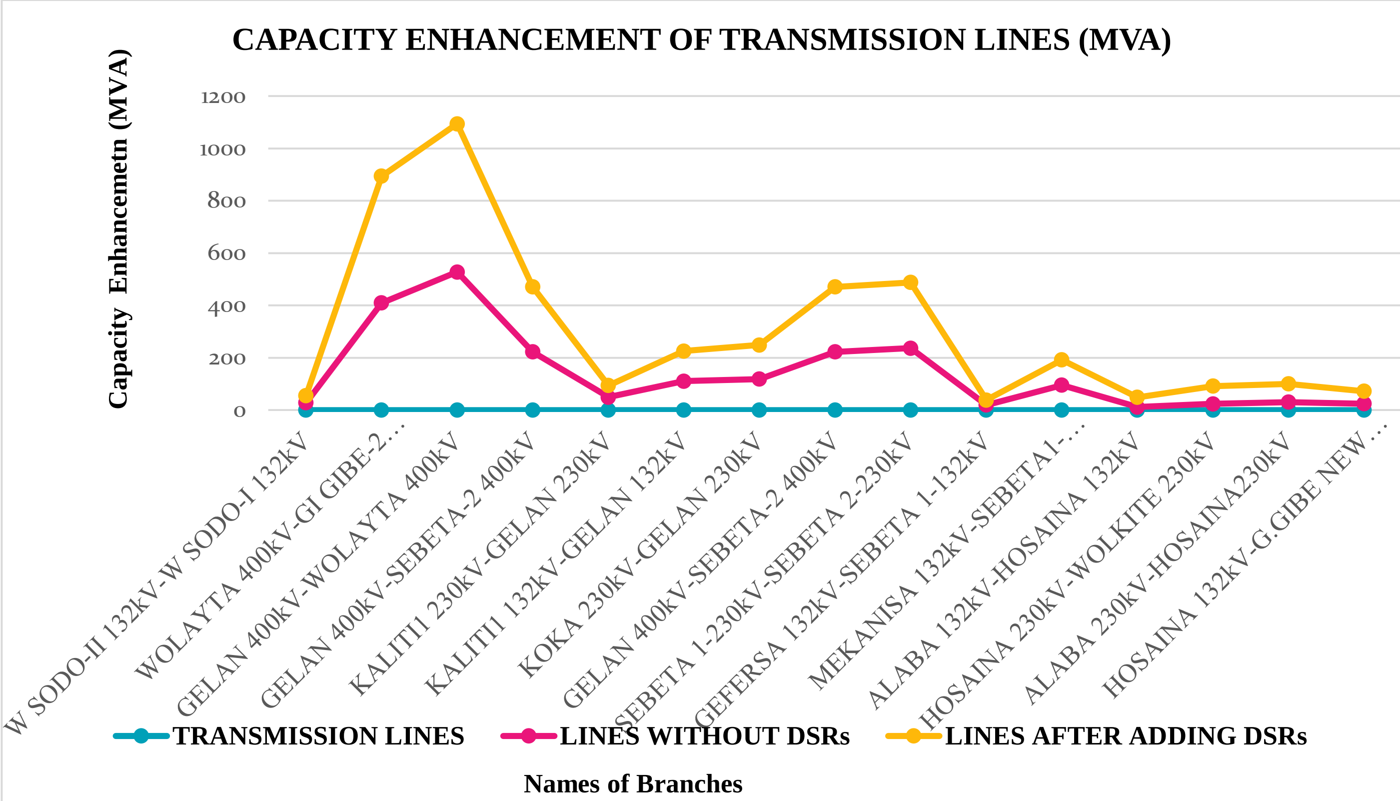


Figure 4-4Comparisons of Power Flows

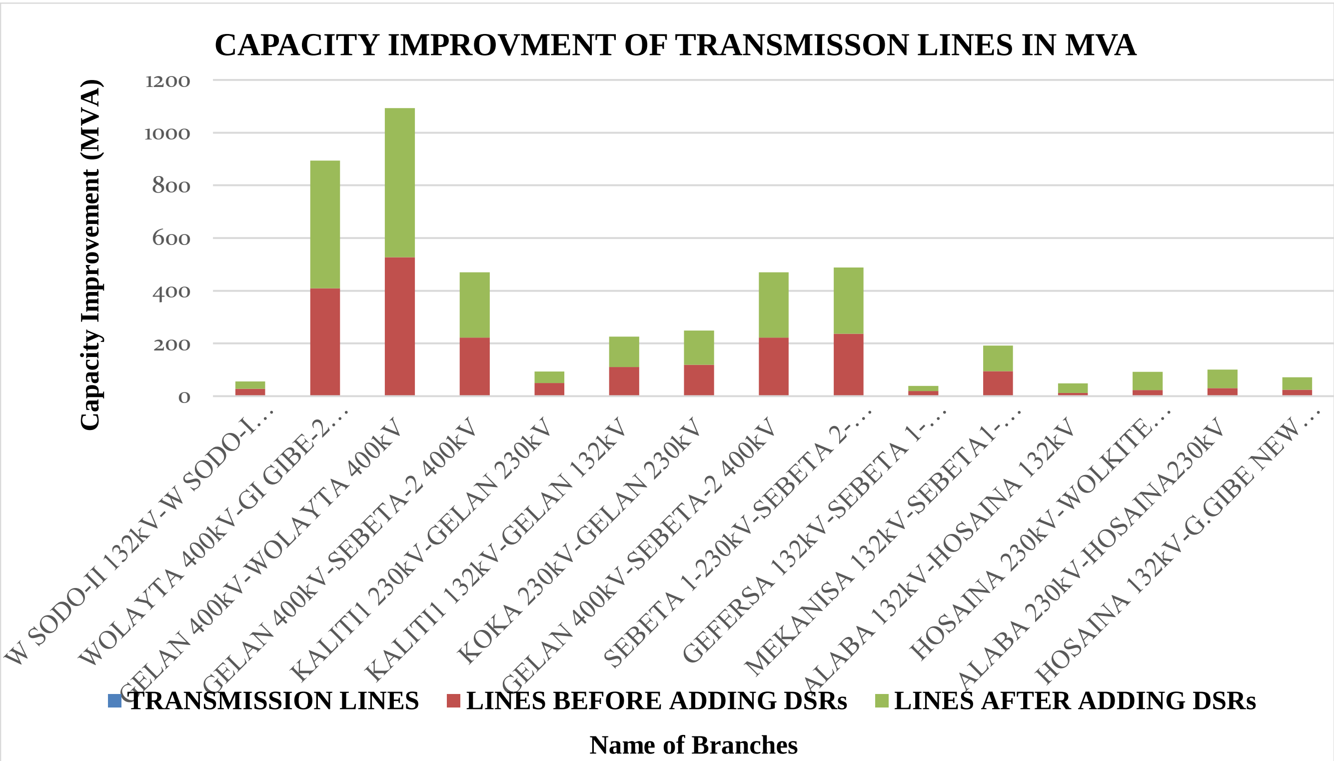


Figure 4- 5 Comparisons of Power Flows

From the figure 3.3 it can be seen that when without DSRs placement to Alaba to Wolyta Sodo II transmission line, Kality to Gelan ,Gefersa to Sebta 1 and Alaba to Hosina 132-kV lines are going to be overloaded while there is still a huge transmission capacity available on Wolyta to Gibe 2 ,Gelan to Wolyta ,Gelan to Sebta I and Gelan to Sebta II 400 kV lines. By adding DSRs to Alaba to Wolyta Sodo II 132-kV line the power flow is shifted to the 400-kV lines. However, this method shifts power flow from all lines which are connected to 132-kV line. As a result, excess power is transferred from Alaba to Wolyta Sodo II 132kV transmission line to its connected branches of the 400kV and 230 kV transmission lines. The capacity enhancement due to placement of DSRs are presented on the following Figure 4.6

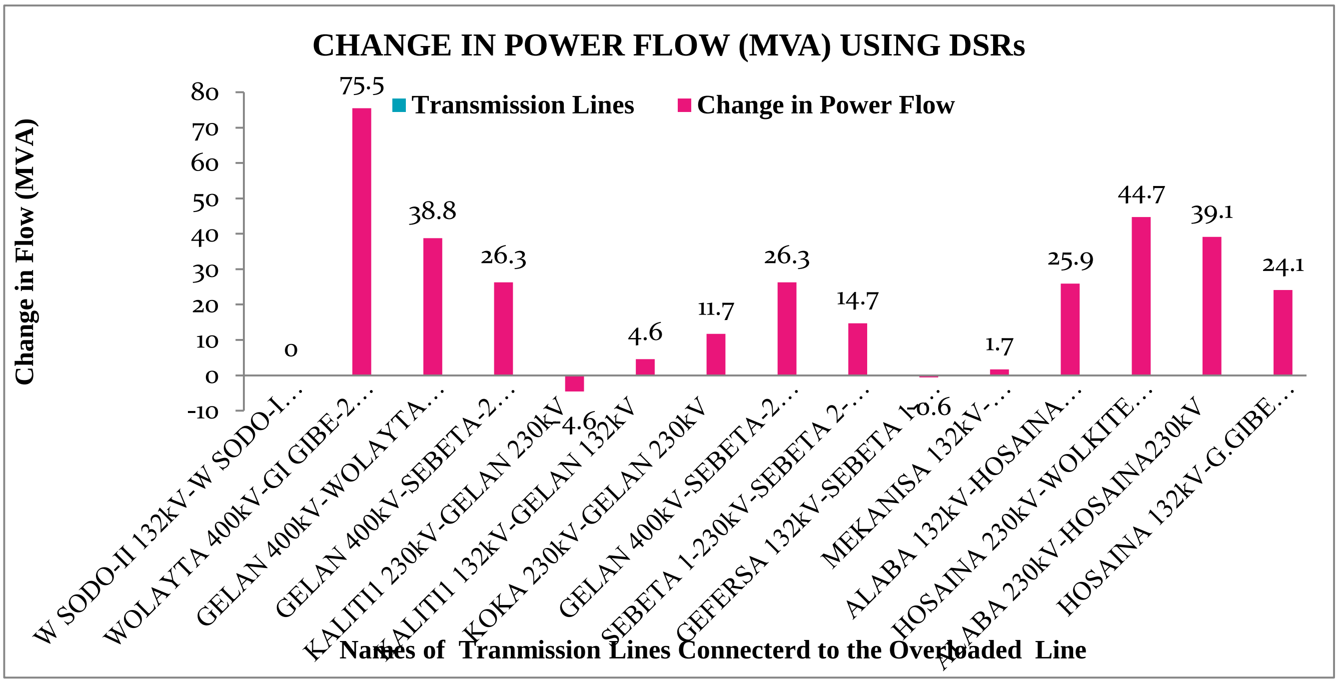


Figure 4-6Changes in Power Flows by Adding DSRs

Voltage profile before and after DSRs Operation

This thesis is done keeping the voltage profile within the range of acceptable standard limits. The following figure 4-7 shows the voltage profile before and after DSRs operation.

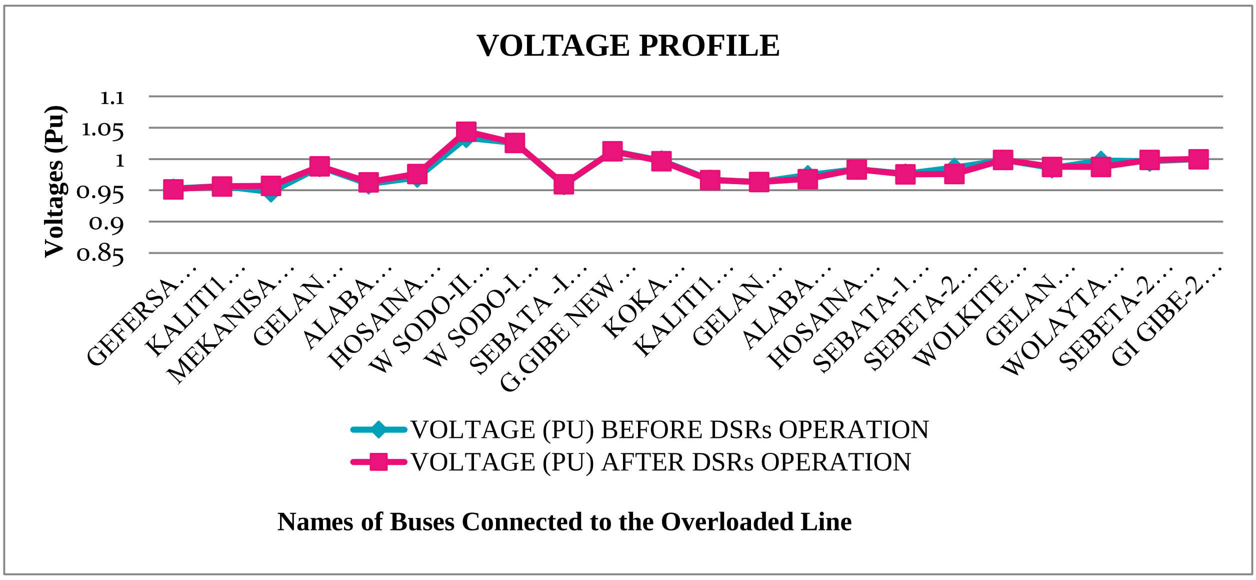


Figure 4-7 voltage profile after and before DSRs operation for branches connected to the overloaded lines

4.5 Cost Benefit Analysis of Using DSRs

In this section the economics approaches to DSR implementation is evaluated in terms of the cost of new transmission line construction. Based on the cost of construction of 132 kV line for 61.81km to enhance the power transfer capacity of the transmission system by 84.8% with the same power transfer capacity of the transmission system for the dollar worth of DSRs implementation is calculated [31]. DSRs are commercially sold with an estimated cost used in the work here of $10,000 per module [29**]**. The cost of new transmission line construction for 132kV line pre-km is 181,924.46 USD/Km [30]**.**

MVA flow increase over the 400-kV line for DSR operation is calculated as follows:

$$Cost\ of\ increase\ MVA\ flow = \frac{change\ in\ MVA\ flow\ due\ to\ DSRs\ on\ the\ \ lines}{The\ loading\ Capacity\ of\ the\ line} \times (Transmission\ line\ length \times Cost\ of\ tranmission\ line\ per\ km)$$

$$Cost\ of\ Increase\ MVA\ flow\ (400kV) = \frac{(75.5+38.8+26.3+26.3)}{1975} 61.81km \times 0.2M\$/km` \quad (4.1)$$

$$= 1.04M\$$$

MVA flow increase over the 230-kV line for DSR operation is calculated as follows:

$$Cost\ of\ Increase\ MVA\ flow\ (230kV) = \frac{(11.7+14.7+44.7+39.1)}{402} (61.81km \times 0.2M\$/km) \quad (4.2)$$

$$=3.39M\$$$

MVA flow increase over the132 kV line for DSR operation is calculated as follows:

$$Cost\ of\ Increase\ MVA\ flow\ (132kV) = \frac{(4.6+1.7+25.9+24.1)}{89} (61.81km \times 0.2M\$/km)` \quad (4.3)$$

$$=7.82M\$$$

Where 1975MVA, 402MVAand 89MVA are the loading capacity of 400,230 and 132kV lines.

The total cost of increase MVA flow is the sum of equation (4.1), (4.2) and (4.3) =**12.25**M$ (4.4)

To calculate the investment cost per DSR the cost of the MVA increase is divided by the number of DSRs giving

$$Cost\ per\ DSR = \frac{12.25M\$}{333} \quad (4.5)$$

=36,787$/DSR

So, the cost for the 333 DSRs deployed for the overloaded line will be

$$333 \times \$10{,}000 = 3.33\text{M}\$ \quad (4.6)$$

Comparing this total cost of DSRs in (4.6) with that of building new lines in (4.4) it appears that the DSRs implementation reduced the cost by 27.18 % relative to the traditional approach of building new lines.

As per the Ethiopian Electric Utility the current price of electricity or electric tariff is at 0.27Cents (ETB) per kilowatt hour (kwh) [1]. The annual rate of return has been calculated using the future and present value:

$$Future\ Value\ (F) = Present\ Value\ (P)(1 + Rate\ of\ return)^{t} \quad (4.7)$$

Where't 'is the time in years.

The investment cost of the DSRs to increase the MVA flow on a transmission line which is considered as the present value 3.33M$ for the year 2018 and the future value after 2 years which is the year 2020 is 5. 6M$.The rate of return from equation (4.7) is:

$$\text{Rate of Retrun} = \left(\frac{\text{F}}{\text{P}}\right)^{\frac{1}{\text{t}}} - 1 \quad (4.8)$$

The rate of return is 30% and which is returned the investment cost within 3.4years.

CHAPTER 5

CONCLUSIONS, RECOMMENDATIONS AND FUTURE WORK

5.1 INTRODUCTION

Based on the results obtained through simulation studies of the existing Wolyta Sodo II – Alaba 132kV transmission line and the system using DSRs at appropriate locations, the following conclusions and recommendation are made in this chapter. Furthermore, suggestions for further investigations of this research are also presented at the end of the chapter.

5.2 CONCLUSIONS

Today's grid meets today's requirements, but new and different demands are driving the expansion and adaptation of the transmission grid and the evolution of its supporting institutions. Meanwhile, transmission infrastructure projects are facing several challenges. Some of these challenges include delayed construction due to sitting and permitting issues, congestion, and under-utilization of already existing transmission facilities.

One of the existing solutions and opportunities to improve transmission capacity is the deployment DSRs and its techniques that better utilize the existing network facilities and improves the capacity of the grid.

This work presents a conclusion on 132kV, 230kV and 400kV transmission system connected to the overloaded Wolyta Sodo II – Alaba 132kV line. The placement of DSRs having its reactance value 20% of overloaded line reactance enhances the capacity utilization of the transmission system by 84.8%.

A cost benefit analysis of DSRs for improving an overloaded Alaba to Wolyta Sodo II transmission line with construction of new line was presented. In the cost benefit analysis, the study of the system with 61.81km the cost of new line construction for enhancing the power flow by 84.8% is 12.25M$. The cost of implementation of DSRs enhancing the same capacity is 3. 33M$.Therefore, the savings become 8.92M$.

DSRs implementation can reduce the cost by 27.18 % in managing capacity enhancement and can delay making investments in new line construction until capacity enhancement is proven to be true. Thus, a major value of DSRs is handling overloads and makes enhanced system operating conditions and is delaying larger investments.

5.3 RECOMNDATIONS

Based on the result analysis of this thesis work, it is strongly recommended that EEP has to implement DSRs on Alaba to Wolyta Sodo II transmission line to enhance the capacity of the transmission system on the existing grid, and EEP transmission planners have to incorporate such kind of studies rather only engaging construction of new transmission lines, as a result the company minimizes cost for budgeting a billion dollars for each year for new line construction.

The power company, EEP has to develop a data base and incorporate to their system for such kinds of research results for future reference during transmission planning which helps the company as well the country for efficiently use un utilized 400kV,230kV and 132kV transmission lines.

5.4 SUGGESTIONS OF FUTURE WORK

Gibe III starts generate power in full capacity, most of the transmission lines and transformers in the system getting overloaded. The loss of any transmission line results in overloading and partial blackout. For effective utilization of all the transmission system DSRs are given the promise for reliable and inexpensive power flow control. Effective implementation of DSRs in our grid needs further studies on EEP transmission system.

1. In this thesis, basically have two modes of operation of DSRs have been considered for simulation studies. Further studies may be carried out to investigate the behavior of transient faults on EEP transmission system.
2. For implementation of DSRs during transient faults, the existing protection coordination scheme of EEP transmission system may be studied.

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APPENDIX A: Summary of Contingency Analysis

Table A-1 Summary of N-1 Contingency

Number of Monitored Branches = 285
Number of Monitored Interfaces = 0
Number of Contingencies Base Case = 303
Number of Voltage Monitored Buses = 282
Number of Voltage Monitored Records = 1
Number of Voltage Monitored Bus Records = 282
Number of Buses in the case = 930
Number of Loads shed due to post contingency = 12
Number of Loads shed due to tripping = 12
Number of Loads shed due to corrective actions = 12

Table A-2Monitored lines

Monitored Lines				
MON#	BRANCHES	RATE A	RATE B	RATE C
1	101001 ADD EAST-II 132.00 101003 COTEBEI-I 132.00 1	91	91	91
2	101001 ADD EAST-II 132.00 101012 ADDIS-NORTH 132.00 1	91	91	91
3	101002 B.WGN-TP 132.00 101003 COTEBEI-I 132.00 1	82	82	82
4	101002 B.WGN-TP 132.00 101005 WERGENU 132.00 1	82	82	82

5	101002 B.WGN-TP 132.00 101017 KALITI1 132.00 1	82	82	82
6	101003 COTEBEI-I 132.00 101007 ADDIS-E1 132.00 1	91	91	91
7	101003 COTEBEI-I 132.00 101007 ADDIS-E1 132.00 2	91	91	91
8	101003 COTEBEI-I 132.00 101009 AYAT 132.00 1	82	82	82
9	101003 COTEBEI-I 132.00 101010 BOLE-LEMI TP132.00 1	82	82	82
10	101004 SULULTA-132 132.00 102036 DANGOTE CEM 132.00 1	115	115	115
11	101004 SULULTA-132 132.00 601001 SULULTA 66.000 1	25	25	25
12	101006 LEGETAFO 132.00 101009 AYAT 132.00 1	82	82	82
13	101006 LEGETAFO 132.00 102001 DEBRE BERHAN132.00 1	82	82	82
14	101010 BOLE-LEMI TP132.00 101011 BOLE-LEMI MB132.00 1	82	82	82
15	101010 BOLE-LEMI TP132.00 101020 KLT.N-TP 132.00 1	82	82	82
16	101012 ADDIS-NORTH 132.00 101014 MINILIK TS 132.00 1	82	82	82
17	101013 GEFERSA 132.00 101014 MINILIK TS 132.00 1	82	82	82
18	101013 GEFERSA 132.00 101017 KALITI1 132.00 1	82	82	82
19	101013 GEFERSA 132.00 101028 SEBATA -I 132.00 1	82	82	82
20	101013 GEFERSA 132.00 102009 HABESHA TP 132.00 1	91	91	91
21	101015 ADDIS CENTER132.00 101017 KALITI1 132.00 1	82	82	82

22	101016 GOFA 132.00 101021 MEKANISA 132.00 1	91	91	91
23	101017 KALITI1 132.00 101019 KALITI TWO 132.00 1	82	82	82
24	101017 KALITI1 132.00 101020 KLT.N-TP 132.00 1	82	82	82
25	101017 KALITI1 132.00 101021 MEKANISA 132.00 1	82	82	82
26	101017 KALITI1 132.00 101022 YESU 132.00 1	115	115	115
27	101017 KALITI1 132.00 101023 GELAN 132.00 1	115	115	402
28	101017 KALITI1 132.00 101024 INDODE TS 132.00 1	115	115	115
29	101017 KALITI1 132.00 101027 KALITI GIS 132.00 1	82	82	82
30	101018 KALTI-NORTH 132.00 101020 KLT.N-TP 132.00 1	82	82	82
31	101019 KALITI TWO 132.00 101025 NEFASILK 132.00 1	91	91	91
32	101019 KALITI TWO 132.00 101027 KALITI GIS 132.00 1	91	91	91
33	101021 MEKANISA 132.00 101028 SEBATA -I 132.00 1	82	82	82
34	101022 YESU 132.00 101023 GELAN 132.00 1	115	115	115
35	101023 GELAN 132.00 101024 INDODE TS 132.00 1	115	115	115
36	101023 GELAN 132.00 102017 ELALA-TP 132.00 1	115	115	115
37	101023 GELAN 132.00 102035 DBZT2-TP 132.00 1	115	115	115
38	101023 GELAN 132.00 102037 KNORIA TEX 132.00 1	115	115	115

39	101028 SEBATA -I 132.00 101030 ADDIS WEST 2132.00 2	91	91	91
40	102001 DEBRE BERHAN132.00 106004 SHOWA-ROBIT 132.00 1	82	82	82
41	102003 DERBA-CEMENT132.00 102006 DERBA-TAP 132.00 1	91	91	91
42	102004 HORMAT 132.00 104005 GHEDO 132.00 1	89	89	89
43	102005 MUGER 132.00 102038 DANGOTE TP 132.00 2	91	91	91
44	102006 DERBA-TAP 132.00 102009 HABESHA TP 132.00 1	91	91	91
45	102006 DERBA-TAP 132.00 102038 DANGOTE TP 132.00 1	91	91	91
46	102008 HABESHA CEM 132.00 102009 HABESHA TP 132.00 1	91	91	91
47	102010 AWASH-7KL 132.00 102020 METAHARA 132.00 1	82	82	82
48	102010 AWASH-7KL 132.00 103001 ASEBETEFIR 132.00 1	115	115	115
49	102010 AWASH-7KL 132.00 103022 SIRBA OUNKUR132.00 1	115	115	115
50	102010 AWASH-7KL 132.00 103023 AWASH TS 132.00 1	115	115	115
51	102012 ADAMI TULU 132.00 102013 ASSELA 132.00 1	82	82	82
52	102012 ADAMI TULU 132.00 102040 BUTAJIRA 132.00 1	91	91	91
53	102012 ADAMI TULU 132.00 105009 SHASHEMENE 132.00 1	82	82	82
54	102013 ASSELA 132.00 102032 WON SUG TP 132.00 1	82	82	82
55	102014 AWASH2 132.00 102015 AWASH-3 132.00 1	82	82	82

56	102014 AWASH2 132.00 102018 KOKA 132.00 1	82	82	82
57	102014 AWASH2 132.00 102022 WONJI-TP 132.00 1	82	82	82
58	102014 AWASH2 132.00 102032 WON SUG TP 132.00 1	82	82	82
59	102014 AWASH2 132.00 102042 WULENCHTI TS132.00 1	82	82	82
60	102016 ELALA-GEDA 132.00 102017 ELALA-TP 132.00 1	82	82	82
61	102017 ELALA-TP 132.00 102018 KOKA 132.00 1	82	82	82
62	102018 KOKA 132.00 102021 NAZRETH2 132.00 1	82	82	82
63	102018 KOKA 132.00 102022 WONJI-TP 132.00 1	82	82	82
64	102018 KOKA 132.00 102031 MOJO II MOB 132.00 1	115	115	115
65	102018 KOKA 132.00 102035 DBZT2-TP 132.00 1	82	82	82
66	102020 METAHARA 132.00 102021 NAZRETH2 132.00 1	82	82	82
67	102020 METAHARA 132.00 102029 MELKAJILO TS132.00 1	82	82	82
68	102021 NAZRETH2 132.00 102030 ADAM-I WIND 132.00 1	82	82	82
69	102022 WONJI-TP 132.00 102024 WONJIPULP 132.00 1	82	82	82
70	102023 M WAK-YUGO 132.00 105009 SHASHEMENE 132.00 1	89	89	89
71	102023 M WAK-YUGO 132.00 105013 YADOT 132.00 1	91	91	91
72	102025 METEHARA-TS 132.00 102029 MELKAJILO TS132.00 1	115	115	115

73	102025 METEHARA-TS 132.00 103023 AWASH TS 132.00 1	115	115	115
74	102026 MODJO TS 132.00 102042 WULENCHTI TS132.00 1	82	82	82
75	102031 MOJO II MOB 132.00 102037 KNORIA TEX 132.00 1	115	115	115
76	102032 WON SUG TP 132.00 102033 WON SUG 132.00 1	82	82	82
77	102034 DB-ZEIT2 132.00 102035 DBZT2-TP 132.00 1	82	82	82
78	103001 ASEBETEFIR 132.00 103014 AFDEM TS 132.00 1	115	115	115
79	103001 ASEBETEFIR 132.00 103025 MIESSO TS 132.00 1	402	402	402
80	103002 DIRE DAWA 1 132.00 103003 DIRE DAWA 3 132.00 1	82	82	82
81	103002 DIRE DAWA 1 132.00 103016 NATIONAL CEM132.00 1	82	82	82
82	103003 DIRE DAWA 3 132.00 103008 D.DAWA-2 132.00 1	82	82	82
83	103003 DIRE DAWA 3 132.00 103009 D.DAW-DS 132.00 1	115	115	115
84	103005 FIK 132.00 103006 HARAR-3 132.00 1	91	91	91
85	103006 HARAR-3 132.00 103008 D.DAWA-2 132.00 1	115	115	115
86	103006 HARAR-3 132.00 103018 JIJIGA I 132.00 1	115	115	115
87	103007 HURSO 132.00 103015 GOTA 132.00 1	115	115	115
88	103014 AFDEM TS 132.00 103015 GOTA 132.00 1	115	115	115
89	103022 SIRBA OUNKUR132.00 103025 MIESSO TS 132.00 1	115	115	115

90	104001 ASSOSA 132.00 104003 MENDI 132.00 1	63	63	63
91	104002 GHIMBI 132.00 104003 MENDI 132.00 1	91	91	91
92	104002 GHIMBI 132.00 104008 NEKEMPTE 132.00 1	89	89	89
93	104005 GHEDO 132.00 104008 NEKEMPTE 132.00 1	89	89	89
94	104007 GIDA-AYANA 132.00 104008 NEKEMPTE 132.00 1	91	91	91
95	104008 NEKEMPTE 132.00 108003 B.BEDELE 132.00 1	91	91	91
96	105002 ARBA MINCH 132.00 105024 W SODO-I 132.00 1	89	89	89
97	105003 ALABA 132.00 105008 HOSAINA 132.00 1	89	89	89
98	105003 ALABA 132.00 105009 SHASHEMENE 132.00 1	89	89	89
99	105003 ALABA 132.00 105025 AWASA MOBILE132.00 1	82	82	82
100	105004 AWASA 132.00 105009 SHASHEMENE 132.00 1	82	82	82
101	105004 AWASA 132.00 105014 YIRGALEM 132.00 1	82	82	82
102	105005 BOCULUGUMA 132.00 105007 HAGER MARIAM132.00 1	115	115	115
103	105006 DILLA 132.00 105007 HAGER MARIAM132.00 1	91	91	91
104	105006 DILLA 132.00 105014 YIRGALEM 132.00 1	91	91	91
105	105008 HOSAINA 132.00 108005 G.GIBE NEW 132.00 1	89	89	89
106	105010 SAWLA 132.00 105017 KEY AFER 132.00 1	115	115	115

107	105010 SAWLA 132.00 105024 W SODO-I 132.00 1	91	91	91
108	105011 SHAKISO 132.00 105014 YIRGALEM 132.00 1	82	82	82
109	105012 W SODO-II 132.00 105024 W SODO-I 132.00 1	89	89	89
110	105024 W SODO-I 132.00 605005 WOLAYTA SODO66.000 1	25	25	25
111	106001 ALEM KETEMA 132.00 106002 AKISTA 132.00 1	91	91	91
112	106002 AKISTA 132.00 106003 COMBOLCHA-I 132.00 1	91	91	91
113	106003 COMBOLCHA-I 132.00 106005 COMBOLCHA-II132.00 1	91	91	91
114	106004 SHOWA-ROBIT 132.00 106006 KEMISSIE 132.00 1	115	115	115
115	106005 COMBOLCHA-II132.00 106006 KEMISSIE 132.00 1	115	115	115
116	107001 B.DAR2 132.00 107002 T-ABAY2 132.00 1	91	91	91
117	107001 B.DAR2 132.00 107002 T-ABAY2 132.00 2	91	91	91
118	108001 ABA 132.00 108007 JIMMA NEW 132.00 1	91	91	91
119	108002 AGARO 132.00 108003 B.BEDELE 132.00 1	89	89	89
120	108003 B.BEDELE 132.00 208004 BEDELLE 230.00 1	40	40	40
121	108004 BONGA 132.00 108008 MIZAN 132.00 1	91	91	91
122	108004 BONGA 132.00 108009 JIMMA OLD 132.00 1	91	91	91
123	108005 G.GIBE NEW 132.00 108006 GI GIBE-1 132.00 1	89	89	89

124	108007 JIMMA NEW 132.00 108009 JIMMA OLD 132.00 1	91	91	91
125	109001 ADIGRAT 132.00 109008 WUKRO-TP 132.00 1	89	89	89
126	109002 ADWA 132.00 109012 ABIADI MB TP132.00 1	89	89	89
127	109004 MEKELE 132.00 109005 MESOBO 132.00 1	89	89	89
128	109004 MEKELE 132.00 109008 WUKRO-TP 132.00 1	89	89	89
129	109004 MEKELE 132.00 109012 ABIADI MB TP132.00 1	89	89	89
130	109004 MEKELE 132.00 209004 MEKELE 230.00 1	63	63	63
131	109007 WUKRO 132.00 109008 WUKRO-TP 132.00 1	89	89	89
132	109012 ABIADI MB TP132.00 109013 ABIADI MB 132.00 1	89	89	89
133	201001 LEGETAFO 230.00 201002 SULULTA 230.00 1	402	402	402
134	201001 LEGETAFO 230.00 201002 SULULTA 230.00 2	402	402	402
135	201001 LEGETAFO 230.00 201004 COTOBEI-I 230.00 1	402	402	402
136	201001 LEGETAFO 230.00 201004 COTOBEI-I 230.00 2	402	402	402
137	201001 LEGETAFO 230.00 201005 BOLEARABSTP 230.00 1	402	402	402
138	201001 LEGETAFO 230.00 206001 COMBOL-II 230.00 1	318	318	318
139	201002 SULULTA 230.00 201007 GEFERSA 230.00 1	318	318	318
140	201002 SULULTA 230.00 201007 GEFERSA 230.00 2	318	318	318

141	201002 SULULTA 230.00 202001 CHANCHO230 230.00 2	402	402	402
142	201005 BOLEARABSTP 230.00 201006 BOLE ARABSE 230.00 1	402	402	402
143	201005 BOLEARABSTP 230.00 201009 KALITI1 230.00 1	402	402	402
144	201007 GEFERSA 230.00 201008 TORHAYILOCH 230.00 1	402	402	402
145	201007 GEFERSA 230.00 204003 GHEDO 230.00 1	280	280	280
146	201007 GEFERSA 230.00 204003 GHEDO 230.00 3	402	402	402
147	201008 TORHAYILOCH 230.00 201011 SEBATA-1 230.00 1	402	402	402
148	201009 KALITI1 230.00 201010 GELAN 230.00 1	331	331	331
149	201009 KALITI1 230.00 201010 GELAN 230.00 2	331	331	331
150	201009 KALITI1 230.00 201011 SEBATA-1 230.00 1	274	274	274
151	201010 GELAN 230.00 201017 EIZ TAP 1 230.00 1	331	331	331
152	201010 GELAN 230.00 202011 KOKA 230.00 1	331	331	331
153	201010 GELAN 230.00 3WNDTR GELAN3WT-1 WND 2 1	500	0	0
154	201010 GELAN 230.00 3WNDTR GELAN3WT-2 WND 2 2	500	0	0
155	201010 GELAN 230.00 3WNDTR GELAN3WT-3 WND 2 3	500	0	0
156	201011 SEBATA-1 230.00 201012 SEBETA-2 230.00 1	280	280	280
157	201011 SEBATA-1 230.00 201012 SEBETA-2 230.00 2	280	280	280

158	201011 SEBATA-1 230.00 202020 WOLKITE 230.00 1	402	402	402
159	201012 SEBETA-2 230.00 201016 SEBETA TS 230.00 1	280	280	280
160	201012 SEBETA-2 230.00 201016 SEBETA TS 230.00 2	280	280	280
161	201017 EIZ TAP 1 230.00 202011 KOKA 230.00 1	274	274	274
162	202003 GEBRE-GURCHA230.00 402001 GEBRE-GURCHA400.00 1	125	125	125
163	202003 GEBRE-GURCHA230.00 402001 GEBRE-GURCHA400.00 2	125	125	125
164	202008 AWSH-7KL 230.00 202011 KOKA 230.00 1	353	353	353
165	202008 AWSH-7KL 230.00 203002 DIRE DAWA3 230.00 1	353	353	353
166	202011 KOKA 230.00 202012 MELKA-WAKNA 230.00 1	257	257	257
167	202011 KOKA 230.00 202012 MELKA-WAKNA 230.00 2	257	257	257
168	202011 KOKA 230.00 202015 ADAMA II WF230.00 1	402	402	402
169	202011 KOKA 230.00 203003 HURSO 230.00 1	402	402	402
170	202011 KOKA 230.00 203003 HURSO 230.00 2	402	402	402
171	202012 MELKA-WAKNA 230.00 202017 M WAK-YUGO 230.00 1	257	257	257
172	202012 MELKA-WAKNA 230.00 205001 RAMO 230.00 1	402	402	402
173	202020 WOLKITE 230.00 205003 HOSAINA 230.00 1	402	402	402
174	202020 WOLKITE 230.00 208006 G.GIBE NEW 230.00 1	280	280	280

175	203001 ADIGALA 230.00 203003 HURSO 230.00 1	402	402	402
176	203001 ADIGALA 230.00 203009 ADIGALA-TS 230.00 1	402	402	402
177	203001 ADIGALA 230.00 203014 MILO TS 230.00 1	402	402	402
178	203002 DIRE DAWA3 230.00 203003 HURSO 230.00 1	255	255	255
179	203002 DIRE DAWA3 230.00 203003 HURSO 230.00 2	255	255	255
180	203003 HURSO 230.00 203013 HURSO TS 230.00 1	402	402	402
181	203008 LONNIS TS 230.00 203013 HURSO TS 230.00 1	402	402	402
182	203008 LONNIS TS 230.00 203014 MILO TS 230.00 1	402	402	402
183	203009 ADIGALA-TS 230.00 203011 AYISHA TS 230.00 1	402	402	402
184	203011 AYISHA TS 230.00 203012 DAWALE TS 230.00 1	402	402	402
185	203015 GODE 230.00 205001 RAMO 230.00 1	402	402	402
186	204001 FINCHA 230.00 204002 FINCHA-II 230.00 1	318	318	318
187	204001 FINCHA 230.00 204003 GHEDO 230.00 1	284	284	284
188	204001 FINCHA 230.00 207002 DEBRE-MARKOS230.00 1	280	280	280
189	204002 FINCHA-II 230.00 204003 GHEDO 230.00 1	318	318	318
190	204002 FINCHA-II 230.00 204004 NESHE 230.00 1	318	318	318
191	204003 GHEDO 230.00 208006 G.GIBE NEW 230.00 1	274	274	274

192	205002 ALABA 230.00 205003 HOSAINA 230.00 1	402	402	402
193	206001 COMBOL-II 230.00 206008 WOLDIYA MOB 230.00 1	318	318	318
194	206001 COMBOL-II 230.00 206011 SEMERA 230.00 1	318	318	318
195	206008 WOLDIYA MOB 230.00 209001 ALAMATA 230.00 1	318	318	318
196	206009 GASHENA 230.00 207003 GASHENA-TAP 230.00 1	318	318	318
197	206010 DITCHETO 230.00 206011 SEMERA 230.00 1	318	318	318
198	207001 BAHIR DAR2 230.00 207004 GONDAR 2 230.00 1	402	402	402
199	207001 BAHIR DAR2 230.00 207004 GONDAR 2 230.00 2	402	402	402
200	207001 BAHIR DAR2 230.00 207006 MOTA 230.00 1	280	280	280
201	207001 BAHIR DAR2 230.00 207007 NIFAS MEW TP230.00 1	318	318	318
202	207002 DEBRE-MARKOS230.00 207006 MOTA 230.00 1	280	280	280
203	207003 GASHENA-TAP 230.00 207007 NIFAS MEW TP230.00 1	318	318	318
204	207003 GASHENA-TAP 230.00 209001 ALAMATA 230.00 1	318	318	318
205	207004 GONDAR 2 230.00 207005 METEMA 230.00 1	318	318	318
206	207004 GONDAR 2 230.00 207005 METEMA 230.00 2	402	402	402
207	207007 NIFAS MEW TP230.00 207008 N.MEWCHA 230.00 1	318	318	318
208	208001 GAMBELA2 230.00 208002 METU 230.00 1	402	402	402

209	208002 METU 230.00 208004 BEDELLE 230.00 1	318	318	318
210	208004 BEDELLE 230.00 208008 AGARO 230.00 1	402	402	402
211	208005 GI GIBE-1 230.00 208006 G.GIBE NEW 230.00 1	274	274	274
212	208005 GI GIBE-1 230.00 208006 G.GIBE NEW 230.00 2	274	274	274
213	208006 G.GIBE NEW 230.00 208007 JIMMA NEW 230.00 1	402	402	402
214	208007 JIMMA NEW 230.00 208008 AGARO 230.00 1	402	402	402
215	209001 ALAMATA 230.00 209007 MEHONI 230.00 1	318	0	0
216	209001 ALAMATA 230.00 209013 ASHEGODA WF 230.00 1	402	402	402
217	209002 ENDASILASIE 230.00 209003 HUMERA 230.00 1	318	318	318
218	209002 ENDASILASIE 230.00 209006 TEKEZE 230.00 1	318	318	318
219	209004 MEKELE 230.00 209006 TEKEZE 230.00 1	318	318	318
220	209004 MEKELE 230.00 209006 TEKEZE 230.00 2	318	318	318
221	209004 MEKELE 230.00 209007 MEHONI 230.00 1	402	402	402
222	209004 MEKELE 230.00 209013 ASHEGODA WF 230.00 1	402	402	402
223	401001 SULULTA 400.00 402001 GEBRE-GURCHA400.00 1	1341	1341	1341
224	401001 SULULTA 400.00 407003 DEBRE MARKOS400.00 1	1341	1341	1341
225	401002 GELAN 400.00 401003 SEBETA-2 400.00 1	1973	1973	1973

226	401002 GELAN 400.00 405001 WOLAYTA 400 400.00 1	1973	1973	1973
227	401002 GELAN 400.00 3WNDTR GELAN3WT-1 WND 1 1	500	0	0
228	401002 GELAN 400.00 3WNDTR GELAN3WT-2 WND 1 2	500	0	0
229	401002 GELAN 400.00 3WNDTR GELAN3WT-3 WND 1 3	500	0	0
230	401003 SEBETA-2 400.00 402004 HOLETA-400 400.00 1	1205	1205	1205
231	401003 SEBETA-2 400.00 402004 HOLETA-400 400.00 2	1205	1205	1205
232	401003 SEBETA-2 400.00 408001 GI GIBE-2 400.00 1	1341	1341	1341
233	404001 GRAN RENAIS 400.00 407002 BELES 400.00 1	543	533	543
234	405001 WOLAYTA 400 400.00 405004 G-GIBE3 400.00 1	1973	1973	1973
235	405001 WOLAYTA 400 400.00 405004 G-GIBE3 400.00 2	1973	1973	1973
236	405001 WOLAYTA 400 400.00 408001 GI GIBE-2 400.00 1	1973	19793	1973
237	407001 BAHIRDAR-II 400.00 407002 BELES 400.00 1	1341	1341	1341
238	407001 BAHIRDAR-II 400.00 407003 DEBRE MARKOS400.00 1	1341	1341	1341
239	408001 GI GIBE-2 400.00 408002 G.GIBE NEW 400.00 1	1341	1341	1341

APPENDIX B: Peak Load 2017 Data's

Table B-1 Load Data's

Bus Number	Bus Name	Area Name	Zone Name	Pload (MW)	Qload (Mvar)
101001	ASSOSA 132.00	ASOSA	BENSHANGUL-G	2.465	1.194
101002	GHIMBI 132.00	ASOSA	OROMIA	0	0
101004	TULUCAPIGOLD132.00	ASOSA	OROMIA	1.9571	0.9479
102004	D.BERHAN 132.00	EASTERN A.A.	AMHARA	1.825	0.8839
102005	SULULTA-132 132.00	EASTERN A.A.	OROMIA	13.1781	6.3824
102007	COTOBI-II 132.00	EASTERN A.A.	ADDIS ABABA	4.8748	2.361
102007	COTOBI-II 132.00	EASTERN A.A.	ADDIS ABABA	26.7472	12.9543
102009	CHANCHO 132.00	EASTERN A.A.	OROMIA	10.3222	4.9993
102013	SHOAXING-LI 132.00	EASTERN A.A.	ADDIS ABABA	11.1226	2.8956
102014	MSP-STEEL 132.00	EASTERN A.A.	ADDIS ABABA	15.5119	7.5146
103001	ASEBETEFIR 132.00	EASTERN	OROMIA	0.0467	0.0226
103002	D.DAWA-1 132.00	EASTERN	DIRE DAWA	0.0205	0.0099
103007	HURSO 132.00	EASTERN	OROMIA	0	0
103008	D.DAWA-2 132.00	EASTERN	DIRE DAWA	38.706	18.7462
103009	D.DAW-DS 132.00	EASTERN	DIRE DAWA	0.0766	0.0371

103010	D.DAWA-TS 132.00	EASTERN	DIRE DAWA	4.1365	2.0034
103013	KEBRIDHER 132.00	EASTERN	SOMALE	0.5	0.242
103016	AFDEM 132.00	EASTERN	AMHARA	4.1365	2.0034
103017	BIKE 132.00	EASTERN	AMHARA	4.1365	2.0034
103019	MEGALA 132.00	EASTERN	AMHARA	4.1365	2.0034
103020	MIESO 132.00	EASTERN	AMHARA	4.1365	2.0034
105022	BERKOT 132.00	JIJIGA	SOMALE	7.1782	3.4766
105024	FAFEM 132.00	JIJIGA	SOMALE	7.1782	3.4766
106002	AKSTA 132.00	NORTH EASTER	AMHARA	2.5094	1.2154
106005	COMBOL-II 132.00	NORTH EASTER	AMHARA	0	0
106006	KEMISSIE 132.00	NORTH EASTER	AMHARA	0	0
106007	ZEMERO 132.00	NORTH EASTER	AMHARA	9.4908	4.5966
107001	B.DAR2 132.00	NORTH WESTER	AMHARA	0	0
108004	GHEDO 132.00	NORTHERN A.A	OROMIA	0	0
108005	GUDER 132.00	NORTHERN A.A	OROMIA	0	0
108006	MUGER 132.00	NORTHERN A.A	OROMIA	0.0766	0.0371
109002	ADWA 132.00	NORTHERN	TIGRAY	0	0
109003	ALAMATA 132.00	NORTHERN	TIGRAY	2.19	1.0607
109004	MEKELE 132.00	NORTHERN	TIGRAY	11.8599	5.744
110001	AWSH-7KL 132.00	SEMERA	OROMIA	10.9597	5.308
110003	DK290 TS 132.00	SEMERA	AFAR	4.1365	2.0034

111001	A.TULU 132.00	SOUTH EASTER	OROMIA	0	0
111002	ASSELA 132.00	SOUTH EASTER	OROMIA	0	0
111003	AWASH2 132.00	SOUTH EASTER	OROMIA	0.9498	0.46
111007	KOKA 132.00	SOUTH EASTER	OROMIA	3.1313	1.5166
111010	METEHARATAP 132.00	SOUTH EASTER	OROMIA	4.1365	2.0034
111016	METEHARA-TS 132.00	SOUTH EASTER	OROMIA	4.1365	2.0034
111018	ABYSSINIAN 132.00	SOUTH EASTER	OROMIA	9.63	4.66
112001	A.CENTER 132.00	SOUTHERN A.A	ADDIS ABABA	30.5063	14.7749
112005	KALITI1 132.00	SOUTHERN A.A	ADDIS ABABA	4.8748	2.361
112009	MEKANISA 132.00	SOUTHERN A.A	ADDIS ABABA	14.0079	6.7843
112011	AKAKI 2 132.00	SOUTHERN A.A	ADDIS ABABA	4.8927	2.3697
112013	INDODE 132.00	SOUTHERN A.A	ADDIS ABABA	4.1365	2.0034
113001	A.MINCH 132.00	SOUTHERN	S.N.N.P	6.2216	3.0132
113002	ALABA 132.00	SOUTHERN	S.N.N.P	0.2262	0.1096
113003	AWASA 132.00	SOUTHERN	S.N.N.P	1.6969	0.8218
113004	BOCU LUGUMA 132.00	SOUTHERN	OROMIA	0	0
113005	DILLA 132.00	SOUTHERN	S.N.N.P	0.1131	0.0548
113008	HOSAINA 132.00	SOUTHERN	S.N.N.P	0.1131	0.0548
113009	S.SHEMEN 132.00	SOUTHERN	OROMIA	4.697	2.2749

113010	SAWLA 132.00	SOUTHERN	S.N.N.P	0.3394	0.1644
113011	SHAKISO 132.00	SOUTHERN	OROMIA	0	0
113012	W.SODO 132.00	SOUTHERN	S.N.N.P	1.9468	0.9429
113014	YIRGALEM 132.00	SOUTHERN	S.N.N.P	0.5657	0.274
113016	YABELO 132.00	SOUTHERN	OROMIA	0	0
114002	SEBATA 132.00	WESTERN A.A.	ADDIS ABABA	14.9052	7.2189
115002	AGARO 132.00	WESTERN	OROMIA	10	5
115003	B.BEDELE 132.00	WESTERN	OROMIA	0	0
115004	BONGA 132.00	WESTERN	S.N.N.P	0.1131	0.0548
115010	NEKEMPTE 132.00	WESTERN	OROMIA	0	0
115011	GIDAMI 132.00	ASOSA	BENSHANGUL-G	1.056	0.512
115013	ATANGO 132.00	WESTERN	OROMIA	0	0
115014	TUM 132.00	WESTERN	S.N.N.P	0.6787	0.3287
202003	CHANCHO230 230.00	NORTHERN A.A	OROMIA	34.2509	16.5885
202003	CHANCHO230 230.00	NORTHERN A.A	OROMIA	3.257	1.5774
202005	FITCHE 2 230.00	EASTERN A.A.	OROMIA	3.1705	1.5355
202008	GEBRE-GURCHA230.00	EASTERN A.A.	OROMIA	11.0959	5.374
203001	ADIGALA 230.00	EASTERN	EXPORT	0	0
203003	DJIB-PK12 230.00	ASOSA	EXPORT	74.6869	37.3434
203006	DIRE-IND-230230.00	EASTERN	DIRE DAWA	0	0
203007	LASARAT 230.00	EASTERN	SOMALE	4.1365	2.0034
203008	LONNIS 230.00	EASTERN	SOMALE	4.1365	2.0034

203010	MIESO 230.00	EASTERN	AMHARA	4.1365	2.0034
203011	SHI-KUL-230 230.00	EASTERN	SOMALE	4.1365	2.0034
203012	SUBURBAN 230.00	EASTERN	OROMIA	4.1365	2.0034
203013	ADIGALA-TS 230.00	EASTERN	EXPORT	4.1365	2.0034
206002	TOSAMETAL 230.00	NORTH EASTER	OROMIA	19.5709	9.4786
206004	WOLDIA 230.00	NORTH EASTER	AMHARA	3.6501	1.7678
206004	WOLDIA 230.00	NORTH EASTER	AMHARA	5.5111	2.6692
206005	SUN-HI-GUL 230.00	SEMERA	AFAR	24.3223	11.7798
206006	TERU 230.00	SEMERA	AFAR	8.1074	3.9266
207001	B.DAR2 230.00	NORTH WESTER	AMHARA	2.19	1.0607
207003	GASHENA 230.00	NORTH WESTER	AMHARA	0	0
207005	GONDAR2 230.00	NORTH WESTER	AMHARA	7.6651	3.7124
207006	METEMA 230.00	NORTH WESTER	EXPORT	180	90
207008	N.MEW TP 230.00	NORTH WESTER	AMHARA	0	0
207009	N.MEWCHA 230.00	NORTH WESTER	AMHARA	0.6844	0.3315
207010	DEJEN 230.00	NORTH WESTER	AMHARA	0.6844	0.3315
207013	SUDAN-GADARE230.00	NORTH WESTER	EXPORT	200.0001	97.1771
207013	SUDAN-GADARE230.00	NORTH WESTER	EXPORT	180	87.177
207013	SUDAN-GADARE230.00	NORTH	EXPORT	20	9.6863

		WESTER			
208007	GINCHI 230.00	NORTHERN A.A	OROMIA	3.2618	1.5798
209002	ENDASILA 230.00	NORTHERN	TIGRAY	1.5728	0.7617
209004	MEKELE 230.00	NORTHERN	TIGRAY	0	0
209008	DALOL 230.00	NORTHERN	AFAR	5.4798	2.654
209009	MEKELEPVC 230.00	NORTHERN	TIGRAY	7.3065	3.5387
210002	DITCHETO 230.00	SEMERA	AFAR	0	0
210003	SEMERA 230.00	SEMERA	AFAR	0	0
211003	MODJO3230 230.00	SOUTH EASTER	OROMIA	16.1247	7.8096
211005	NAZERET-ADAM230.00	SOUTH EASTER	OROMIA	13.1777	6.3823
212002	DUKEM230 230.00	SOUTHERN A.A	OROMIA	46.6439	22.5907
212003	DB-ZEIT3230 230.00	SOUTHERN A.A	OROMIA	83.7242	40.5495
212003	DB-ZEIT3230 230.00	SOUTHERN A.A	OROMIA	41.0055	19.8599
212005	AKAKI2-230 230.00	SOUTHERN A.A	ADDIS ABABA	100.0001	50
213002	RAMO 230.00	EASTERN	OROMIA	1.0406	0.5037
213006	GINIR 230.00	SOUTHERN	OROMIA	0	0
215005	JIMMA 230.00	WESTERN	OROMIA	50	26
414001	SEBETA-2 400.00	WESTERN A.A.	OROMIA	200	100
507001	GRAN RENAIS 500.00	NORTH WESTER	BENSHANGUL-G	70	35
507003	HOLETA-500 500.00	NORTHERN A.A	OROMIA	23.6416	11.4502

507003	HOLETA-500 500.00	NORTHERN A.A	OROMIA	4.7384	2.2949
507006	SUDAN-RABAK 500.00	NORTH WESTER	EXPORT	70	33.902
602002	FITCHE 2 66.000	EASTERN A.A.	OROMIA	13.9593	6.7609
602002	FITCHE 2 66.000	EASTERN A.A.	OROMIA	17.868	8.6539
603003	BEDDESA 66.000	EASTERN	OROMIA	0.0167	0.008
603006	HARAR1 66.000	EASTERN	HARARI	0	0
604002	GAMBELA1 66.000	GAMBELA	GAMBELA	0.9525	0.4613
606003	DESIE 66.000	NORTH EASTER	AMHARA	1.46	0.7071
606004	LALIBELA 66.000	NORTH EASTER	AMHARA	1.5728	0.7617
606005	SEKOTA 66.000	NORTH EASTER	AMHARA	1.5728	0.7617
607001	B.DAR1 66.000	NORTH WESTER	AMHARA	13.0338	6.3125
607004	DABAT 66.000	NORTH WESTER	AMHARA	1.3688	0.6629
607005	DANGLA 66.000	NORTH WESTER	AMHARA	0	0
607007	FNOT-SLM 66.000	NORTH WESTER	AMHARA	0.6844	0.3315
607008	GONDAR2 66.000	NORTH WESTER	AMHARA	0	0
607011	WORETA 66.000	NORTH WESTER	AMHARA	2.5164	1.2188
608004	GEFERSA 66.000	SOUTHERN	OROMIA	0	0
609002	ADWA 66.000	NORTHERN	TIGRAY	0	0

609005	SHIRE 66.000	NORTHERN	TIGRAY	0	0
611001	BALEROBE 66.000	SOUTH EASTER	OROMIA	0	0
613001	NEG-BORE 66.000	SOUTHERN	OROMIA	0	0
613003	SHAKISO 66.000	SOUTHERN	OROMIA	0.274	0.1327
614003	WOLKITE 66.000	WESTERN A.A.	S.N.N.P	2.0377	0.9869
615002	TEPI 66.000	WESTERN	S.N.N.P	1.6057	0.7777
712002	AKAKI 45.000	SOUTHERN A.A	ADDIS ABABA	1.3652	0.6612
712007	KALITI1 45.000	SOUTHERN A.A	ADDIS ABABA	16.4189	7.9521
714002	ADDIS-W2 45.000	WESTERN A.A.	ADDIS ABABA	16.6264	8.0426
801001	ASSOSA 33.000	ASOSA	BENSHANGUL-G	1.1672	0.5653
801002	GHIMBI 15.000	ASOSA	OROMIA	3.3683	1.6313
801003	MENDI 33.000	ASOSA	OROMIA	2.8615	1.3858
801004	ASSOSA 15.000	ASOSA	BENSHANGUL-G	2.7234	1.3191
802001	ADDIS-E1 15.000	EASTERN A.A.	ADDIS ABABA	12	5.882
802002	B.WRGENU 15.000	EASTERN A.A.	ADDIS ABABA	61.4667	29.7697
802005	D.BERHAN 15.000	EASTERN A.A.	AMHARA	8.2854	4.0129
802008	SULULTA-15 15.000	EASTERN A.A.	OROMIA	35.3638	17.1274
802009	ADDIS-E2 15.000	EASTERN A.A.	ADDIS ABABA	58.0066	28.094
802010	COTOBIE-15B215.000	EASTERN	ADDIS ABABA	41.9436	20.3142

		A.A.			
802012	SULULTA-33 33.000	EASTERN A.A.	OROMIA	3.7225	1.8029
802016	BOLE-LEMI 33.000	EASTERN A.A.	ADDIS ABABA	9.7907	4.7418
802016	BOLE-LEMI 33.000	EASTERN A.A.	ADDIS ABABA	33.5044	16.2269
802018	FITCHE 2 15.000	EASTERN A.A.	OROMIA	7.0727	3.4255
802019	SHEGOLE 15.000	NORTHERN A.A	OROMIA	13.1919	6.3891
802020	DASHEN_BEER 33.000	ASOSA	TIGRAY	10	4.84
803001	A.TEFERI 15.000	EASTERN	OROMIA	4.6685	2.2611
803002	ADIGALA 33.000	EASTERN	EXPORT	0.2888	0.1398
803003	ALEMAYA 15.000	EASTERN	OROMIA	5.5829	2.7039
803004	ALEMAYA-33 33.000	EASTERN	OROMIA	2.9043	1.4066
803005	ASEBE-33 33.000	EASTERN	OROMIA	0.0373	0.018
803006	BABILE 15.000	EASTERN	OROMIA	1.7972	0.8704
803007	BEDESSA 15.000	EASTERN	OROMIA	4.3025	2.0839
803008	CHELENKO 15.000	EASTERN	OROMIA	3.8033	1.842
803009	D.DAWA1- 15.000	EASTERN	DIRE DAWA	0	0
803010	D.DAWA-2 15.000	EASTERN	DIRE DAWA	4.8722	2.3598
803011	D.DAWA3 15.000	EASTERN	DIRE DAWA	3.3472	1.6212
803012	FIK 33.000	EASTERN	OROMIA	0	0
803013	HARAR 15.000	EASTERN	HARARI	5.3939	2.6124
803014	HARAR3 33.000	EASTERN	HARARI	7.3401	3.5549
803017	D.DAWA1- 15.000	EASTERN	DIRE DAWA	15.7109	7.6091
803018	HARAR3 15.000	EASTERN	HARARI	4.805	2.3272

803020	SHI-KULEN IR33.000	EASTERN	SOMALE	24.6294	11.9286
803022	DIRE-IND 33.000	EASTERN	DIRE DAWA	102.9624	49.867
804001	DEMBI DO 15.000	GAMBELA	OROMIA	3.0639	1.484
804002	GAMBELA1 15.000	GAMBELA	GAMBELA	2.4726	1.1975
804004	METU 33.000	GAMBELA	OROMIA	0.8411	0.4073
804005	SOR 15.000	GAMBELA	OROMIA	0	0
804006	METU 15.000	GAMBELA	OROMIA	1.9036	0.922
805001	JIJIGA 15.000	JIJIGA	SOMALE	0	0
805002	JIJIGA2 33.000	JIJIGA	SOMALE	6.9642	3.3729
805003	JIJIGA2 15.000	JIJIGA	SOMALE	10.1109	4.8969
806001	A-KETEMA 33.000	NORTH EASTER	AMHARA	3.6823	1.7834
806002	AKSTA 33.000	NORTH EASTER	AMHARA	9.6142	4.6564
806003	COMBOL-1 15.000	NORTH EASTER	AMHARA	19.2133	9.3054
806004	DESIE 15.000	NORTH EASTER	AMHARA	12.2432	5.9297
806005	LALIBELA 15.000	NORTH EASTER	AMHARA	1.8376	0.89
806006	SEKOTA 15.000	NORTH EASTER	AMHARA	1.5408	0.7463
806007	SHWA-RBT 15.000	NORTH EASTER	AMHARA	3.7577	1.8199
806012	COMBOLIND 33.000	NORTH EASTER	AMHARA	110.016	53.2832
807002	B.DAR2-1 15.000	NORTH WESTER	AMHARA	15.0504	7.2893
807003	BITCHENA 15.000	NORTH WESTER	AMHARA	4.7812	2.3156

807004	DABAT 15.000	NORTH WESTER	AMHARA	3.8016	1.8412
807005	DANGLA 15.000	NORTH WESTER	AMHARA	10.3343	5.0052
807006	DB-MRKOS 15.000	NORTH WESTER	AMHARA	4.7068	2.2797
807007	FNOT-SLM 15.000	NORTH WESTER	AMHARA	9.1334	4.4235
807008	GASHENA 33.000	NORTH WESTER	AMHARA	6.1606	2.9837
807010	GONDER1 15.000	NORTH WESTER	AMHARA	1.568	0.7594
807011	METEMA 33.000	NORTH WESTER	EXPORT	3.7227	1.8031
807012	MOTA 33.000	NORTH WESTER	AMHARA	3.1319	1.5168
807014	N-MEWCHA 33.000	NORTH WESTER	AMHARA	4.1071	1.9891
807015	PAWIE 15.000	NORTH WESTER	BENSHANGUL-G	4.3268	2.0956
807017	B.DAR2-2 15.000	NORTH WESTER	AMHARA	6.5461	3.1705
807019	GONDAR2 15.000	NORTH WESTER	AMHARA	23.2578	11.2643
807021	WORETA 15.000	NORTH WESTER	AMHARA	7.5267	3.6454
807022	GONDER 15.000	NORTH WESTER	AMHARA	1.5544	0.7528
808002	ADDIS-N 15.000	NORTHERN A.A	ADDIS ABABA	60.8985	29.4945
808004	FINCHAA 15.000	NORTHERN A.A	OROMIA	4.0938	1.9826
808005	FNCH-SG1 15.000	NORTHERN	OROMIA	5.1809	2.5092

		A.A			
808006	FNCH-SG2 15.000	NORTHERN A.A	OROMIA	4.0132	1.9437
808008	GEFERSA 15.000	NORTHERN A.A	OROMIA	18.2972	8.8618
808009	GHEDO 15.000	NORTHERN A.A	OROMIA	3.4287	1.6606
808010	GINCHI 15 15.000	NORTHERN A.A	OROMIA	4.6364	2.2455
808011	GUDER 15.000	NORTHERN A.A	OROMIA	9.0285	4.3727
808012	MUGER 15.000	NORTHERN A.A	OROMIA	17.0056	8.2362
808016	MUGER2 15.000	NORTHERN A.A	OROMIA	21.4868	10.4065
809001	ADIGRAT 15.000	NORTHERN	TIGRAY	6.1998	3.0028
809002	ADWA 15.000	NORTHERN	TIGRAY	12.1704	5.8944
809003	ALAMATA1 15.000	NORTHERN	TIGRAY	0	0
809004	HUMERA 33.000	NORTHERN	TIGRAY	4.2407	2.0539
809005	MAYCHEW 15.000	NORTHERN	TIGRAY	2.4981	1.2099
809006	MEKELE 15.000	NORTHERN	TIGRAY	22.4273	10.862
809007	MESOBO 6.3000	NORTHERN	TIGRAY	39.4996	19.1305
809008	SHIRE ENDASI15.000	NORTHERN	TIGRAY	2.8796	1.3946
809011	WUKRO 15.000	NORTHERN	TIGRAY	4.2031	2.0356
809012	ALAMATA2 15.000	NORTHERN	TIGRAY	2.3468	1.1366
809013	SHIRE ENDASI33.000	NORTHERN	TIGRAY	4.0855	1.9787
809014	SHIRE-33-2 15.000	NORTHERN	TIGRAY	0	0
809014	SHIRE-33-2 15.000	NORTHERN	TIGRAY	0	0
809015	MEHONI33 33.000	NORTHERN	TIGRAY	5.6333	2.7284

809016	DANSHA 33.000	NORTHERN	TIGRAY	5.6333	2.7284
810001	AMIBARA 15.000	SEMERA	OROMIA	4.2434	2.0552
810003	AWSH-7KL 15.000	SEMERA	OROMIA	4.54	2.1989
810004	DITCHETO 33.000	SEMERA	AFAR	0	0
810005	SEMERA 33.000	SEMERA	AFAR	6.8075	3.297
811001	A.TULU 15.000	SOUTH EASTER	OROMIA	9.5004	4.6012
811004	ASSELA 15.000	SOUTH EASTER	OROMIA	13.9584	6.7603
811005	AWASH II 15.000	SOUTH EASTER	OROMIA	4.2508	2.0587
811006	AWASH-2 15.000	SOUTH EASTER	OROMIA	3.8387	1.8591
811007	AWASH-3 15.000	SOUTH EASTER	OROMIA	0	0
811008	BALEROBE 15.000	SOUTH EASTER	OROMIA	8.0376	3.8928
811009	ELALA-GD 15.000	SOUTH EASTER	OROMIA	9.7978	4.7453
811010	GOBESSA 33.000	SOUTH EASTER	OROMIA	2.4531	1.1881
811011	KOKA 15.000	SOUTH EASTER	OROMIA	4.1279	1.9992
811012	KOKA2 15 15.000	SOUTH EASTER	OROMIA	0	0
811013	M.WK-YUG 15.000	SOUTH EASTER	OROMIA	6.8437	3.3145
811014	METAHARA 15.000	SOUTH EASTER	OROMIA	10.2032	4.9416
811015	MODJO 15.000	SOUTH EASTER	OROMIA	3.9349	1.9058

811016	NAZ-II 15.000	SOUTH EASTER	OROMIA	35.173	17.035
811017	NAZRET1 15.000	SOUTH EASTER	OROMIA	0	0
811018	NURAERA 15.000	SOUTH EASTER	OROMIA	3	1.23
811019	WONJIPUL 15.000	SOUTH EASTER	OROMIA	17.0492	8.2573
812001	A.CENTER 15.000	SOUTHERN A.A	ADDIS ABABA	60.8985	29.4945
812003	ADS-II 15.000	SOUTHERN A.A	ADDIS ABABA	56.3494	27.2913
812004	AKAKI 15.000	SOUTHERN A.A	ADDIS ABABA	7.2205	3.4971
812005	AKAKI-SP 15.000	SOUTHERN A.A	ADDIS ABABA	8.887	4.3041
812008	DB-ZEIT2 15.000	SOUTHERN A.A	OROMIA	46.5388	22.2337
812009	DUKEM 15.000	SOUTHERN A.A	OROMIA	1.3098	0.6344
812010	KALITI1 15.000	SOUTHERN A.A	ADDIS ABABA	19.0819	9.2418
812011	KALITI2- 15.000	SOUTHERN A.A	ADDIS ABABA	23.0585	11.1678
812012	KALTI-N 15.000	SOUTHERN A.A	ADDIS ABABA	14.6238	7.0826
812013	MEKANISA 15.000	SOUTHERN A.A	ADDIS ABABA	45	22
812014	NEFASILK 15.000	SOUTHERN A.A	ADDIS ABABA	23.6198	11.4396
812015	YESU 15.000	SOUTHERN A.A	OROMIA	6.405	3.1021
812018	KILINTO15 15.000	SOUTHERN	TIGRAY	23.8058	11.5297

		A.A			
812019	DB-ZEIT3 15.000	SOUTHERN A.A	OROMIA	2.653	1.2849
812020	EAST INDUSTR33.000	SOUTHERN A.A	OROMIA	20	9.69
813001	ALABA 15.000	SOUTHERN	S.N.N.P	5.3829	2.607
813002	A.MINCH 15.000	SOUTHERN	S.N.N.P	12.841	6.2192
813003	AWASA 15.000	SOUTHERN	S.N.N.P	19.4072	9.3994
813004	BOCU LUGUMA 33.000	SOUTHERN	OROMIA	6.1134	2.9608
813005	DILLA 33.000	SOUTHERN	S.N.N.P	3.5122	1.701
813006	DILLA-1 15.000	SOUTHERN	S.N.N.P	0	0
813007	H-MARIAM 33.000	SOUTHERN	OROMIA	4.4963	2.1776
813008	HOSAINA 15.000	SOUTHERN	S.N.N.P	8.0614	3.9043
813009	NEG-BORE 33.000	SOUTHERN	OROMIA	1.6353	0.792
813010	S.SHME-1 15.000	SOUTHERN	OROMIA	29.8521	14.458
813011	SAWLA 33.000	SOUTHERN	S.N.N.P	2.3877	1.1564
813012	SHAKISO 15.000	SOUTHERN	OROMIA	11.2166	5.4325
813013	W.SODO 15.000	SOUTHERN	S.N.N.P	10.9331	5.2952
813014	YADOT 33.000	SOUTHERN	OROMIA	0	0
813015	YIRGALEM 15.000	SOUTHERN	S.N.N.P	0	0
813016	DILLA-2 15.000	SOUTHERN	S.N.N.P	12.171	5.8947
813017	NEG-BORE 15.000	SOUTHERN	OROMIA	2.8583	1.3843
813018	YIRGALEM 15.000	SOUTHERN	S.N.N.P	14.0488	6.8042
813019	YIRGALEM 33.000	SOUTHERN	S.N.N.P	3.5122	1.701
813021	GODE33 33.000	SOUTHERN	SOMALE	4.6827	2.2675
813032	AWASA15-2 15.000	SOUTHERN	S.N.N.P	5.4695	2.649
813034	YIRGALEM 15.000	SOUTHERN	S.N.N.P	1.7161	0.8313

813035	YIRGALEM-IND33.000	SOUTHERN	S.N.N.P	91.966	44.541
813036	AWASA INDUST33.000	SOUTHERN	S.N.N.P	81.7326	39.5848
813036	AWASA INDUST33.000	SOUTHERN	S.N.N.P	91.9658	44.5409
814001	ADDIS-W1 15.000	WESTERN A.A.	ADDIS ABABA	16.6264	8.0426
814003	BUTAJIRA 15.000	WESTERN A.A.	S.N.N.P	6.0378	2.9243
814004	GEDJA 15.000	WESTERN A.A.	ADDIS ABABA	5	2.3
814005	SABATA-B 15.000	WESTERN A.A.	ADDIS ABABA	22.2775	10.7895
814005	SABATA-B 15.000	WESTERN A.A.	ADDIS ABABA	28.3916	13.7507
814007	WOLISO 15.000	WESTERN A.A.	OROMIA	13.6221	6.5975
814008	WOLKITE 33.000	WESTERN A.A.	S.N.N.P	2.9257	1.417
814009	BUTAJIRA33 33.000	WESTERN A.A.	S.N.N.P	3.565	1.7265
814011	WOLISO-33 33.000	WESTERN A.A.	OROMIA	1.946	0.9425
814012	WOLKITE 15.000	WESTERN A.A.	S.N.N.P	4.4948	2.177
814013	BLACK-LION 15.000	WESTERN A.A.	ADDIS ABABA	21.0672	10.2033
814020	BUE33 33.000	WESTERN A.A.	S.N.N.P	3	1.4529
814021	BUE15 15.000	WESTERN A.A.	S.N.N.P	2	0.9686
815001	ABA 15.000	WESTERN	OROMIA	4.1747	2.0218
815002	AGARO 15.000	WESTERN	OROMIA	6.0808	2.9451

815003	B.BEDELE 15.000	WESTERN	OROMIA	8.3926	4.0647
815004	BONGA 15.000	WESTERN	S.N.N.P	5.8031	2.8105
815005	G.GIBE 15.000	WESTERN	OROMIA	3.1712	1.5359
815007	GIDA-AYANA 33.000	WESTERN	OROMIA	8.7546	4.24
815008	JIMMA 15.000	WESTERN	OROMIA	11.6933	5.6633
815009	MIZAN 33.000	WESTERN	S.N.N.P	1.6639	0.8059
815010	NEKEMPTE 15.000	WESTERN	OROMIA	7.1112	3.4441
815011	TEPI 15.000	WESTERN	S.N.N.P	2.886	1.3978
815013	BONGA 33.000	WESTERN	S.N.N.P	2.1938	1.0625

Table B-2 Branches Data's

From Bus Number	From Bus Name	To Bus Number	To Bus Name	Line R (pu)	Line X (pu)	Charging B (pu)	Rate A ,Band C phases	Length
101001	ASSOSA 132.00	101003	MENDI 132.00	0.097877	0.195833	0.03766	91	80
101002	GHIMBI 132.00	101003	MENDI 132.00	0.15905	0.318229	0.06119	91	130
101002	GHIMBI 132.00	101004	TULUCAPIGOLD132.00	0.0909	0.1714	0.03295	115	70
101002	GHIMBI 132.00	107008	DEDSSA 132.00	0.0659	0.1242	0.02389	115	50.75
101002	GHIMBI 132.00	115010	NEKEMPTE 132.00	0.108689	0.204569	0.03963	89	84.29
101002	GHIMBI 132.00	115010	NEKEMPTE 132.00	0.1097	0.2052	0.04019	115	84.29
101002	GHIMBI 132.00	115015	KAMASHI 132.00	0.2277	0.4261	0.08341	115	175
101003	MENDI 132.00	115011	GIDAMI 132.00	0.194883	0.367188	0.070606	115	150
102001	ADE-II 132.00	102003	COTOBI-I 132.00	0.006679	0.013363	0.00257	91	5.46
102001	ADE-II 132.00	108001	ADDIS-N 132.00	0.012156	0.024323	0.00468	91	9.94
102002	B.WGN-TP 132.00	102003	COTOBI-I 132.00	0.003664	0.005967	0.00114	82	2.45
102002	B.WGN-TP 132.00	102006	B.WRGENU 132.00	0.00673	0.010959	0.0021	82	4.5

102002	B.WGN-TP 132.00	112005	KALITI1 132.00	0.0129	0.0197	0.00378	103	8.1
102003	COTOBI-I 132.00	102004	D.BERHAN 132.00	0.160706	0.261701	0.05018	82	107.46
102003	COTOBI-I 132.00	102010	ADDIS-E1 132.00	0.00114	0.00713	0.05777	100	6
102003	COTOBI-I 132.00	102010	ADDIS-E1 132.00	0.00114	0.00713	0.05777	100	6
102003	COTOBI-I 132.00	102012	AYAT TS 132.00	0.010469	0.017047	0.003272	82	7
102003	COTOBI-I 132.00	112016	KILINTO 132.00	0.011024	0.016804	0.003222	103	6.9
102004	D.BERHAN 132.00	102014	MSP-STEEL 132.00	0.087038	0.141737	0.027179	82	58.2
102004	D.BERHAN 132.00	102015	DEBRE-BIREHA132.00	0.00095	0.00594	0.04814	100	5
102004	D.BERHAN 132.00	106004	SHWA-RBT 132.00	0.085976	0.140007	0.02685	82	57.49
102005	SULULTA-132 132.00	112015	DANGOTECEM 132.00	0.0806	0.1518	0.02918	115	62
102007	COTOBI-II 132.00	102012	AYAT TS 132.00	0.001496	0.002435	0.000467	82	1
102007	COTOBI-II 132.00	102013	SHOAXING-LI 132.00	0.05982	0.097414	0.01868	82	40
102007	COTOBI-II 132.00	102015	DEBRE-BIREHA132.00	0.14955	0.243534	0.0467	82	100
102013	SHOAXING-LI 132.00	102014	MSP-STEEL 132.00	0.002692	0.004384	0.000841	82	1.8
103001	ASEBETEFIR 132.00	103020	MIESO 132.00	0.035332	0.066571	0.012801	115	27.2
103002	D.DAWA-1 132.00	103003	D.DAWA-3 132.00	0.005491	0.008943	0.00171	82	3.67
103003	D.DAWA-3 132.00	103004	DD.DS-TP 132.00	0.005384	0.008767	0.00168	82	3.6
103003	D.DAWA-3 132.00	103008	D.DAWA-2 132.00	0.018588	0.030269	0.0058	82	12.43
103003	D.DAWA-3 132.00	103009	D.DAW-DS 132.00	0.004677	0.008812	0.001695	115	3.6
103004	DD.DS-TP 132.00	103009	D.DAW-DS 132.00	0.002835	0.004617	0.00089	82	1.9
103004	DD.DS-TP 132.00	110001	AWSH-7KL 132.00	0.306578	0.499244	0.09572	82	205
103005	FIK 132.00	103006	HARAR-3 132.00	0.188288	0.376729	0.07244	91	153.9
103006	HARAR-3	103011	ALEMAYA 132.00	0.030934	0.058285	0.011207	115	23.81

	132.00							
103006	HARAR-3 132.00	103012	BABILE 132.00	0.03248	0.061198	0.011768	115	25
103006	HARAR-3 132.00	103015	HARAR-4 132.00	0.0052	0.0098	0.00188	115	4
103007	HURSO 132.00	103010	D.DAWA-TS 132.00	0.020398	0.038432	0.00739	115	15.7
103007	HURSO 132.00	103019	MEGALA 132.00	0.025919	0.048836	0.009391	115	19.95
103008	D.DAWA-2 132.00	103011	ALEMAYA 132.00	0.035079	0.066094	0.012709	115	27
103009	D.DAW-DS 132.00	103010	D.DAWA-TS 132.00	0.008185	0.015422	0.002965	115	6.3
103012	BABILE 132.00	105001	JIJIGA2 132.00	0.090945	0.171354	0.032949	115	70
103013	KEBRIDHER 132.00	113006	GODE 132.00	0.2274	0.4284	0.08237	115	175
103016	AFDEM 132.00	103017	BIKE 132.00	0.034689	0.065359	0.012568	115	26.7
103016	AFDEM 132.00	103020	MIESO 132.00	0.055217	0.104037	0.020005	115	42.5
103017	BIKE 132.00	103019	MEGALA 132.00	0.059114	0.11138	0.021417	115	45.5
103020	MIESO 132.00	110003	DK290 TS 132.00	0.05866	0.110523	0.021252	115	45.15
105001	JIJIGA2 132.00	105024	FAFEM 132.00	0.1169	0.2203	0.043236	115	90
105022	BERKOT 132.00	108014	DEGEHABUR 132.00	0.0922	0.1738	0.03342	115	71
105024	FAFEM 132.00	108014	DEGEHABUR 132.00	0.1169	0.2203	0.04236	115	90
106001	A-KETEMA 132.00	106002	AKSTA 132.00	0.183755	0.36766	0.0707	91	150.19
106002	AKSTA 132.00	106003	COMBOL-I 132.00	0.129687	0.259479	0.04989	91	106
106002	AKSTA 132.00	106003	COMBOL-I 132.00	0.1379	0.2581	0.05054	115	106
106003	COMBOL-I 132.00	106005	COMBOL-II 132.00	0.008564	0.017135	0.00329	91	7
106003	COMBOL-I 132.00	106005	COMBOL-II 132.00	0.0091	0.017	0.00334	115	7
106003	COMBOL-I 132.00	106005	COMBOL-II 132.00	0.0091	0.017	0.00334	115	7
106003	COMBOL-I 132.00	106006	KEMISSIE 132.00	0.049436	0.092514	0.018119	115	38
106003	COMBOL-I 132.00	106008	DESSIE 132.00	0.0165	0.0311	0.00598	115	12.7
106004	SHWA-RBT 132.00	106006	KEMISSIE 132.00	0.104076	0.194766	0.038145	115	80
106004	SHWA-RBT	106007	ZEMERO 132.00	0.1951	0.3652	0.07152	115	150

	132.00							
107001	B.DAR2 132.00	107002	T-ABAY2 132.00	0.035482	0.070505	0.01381	91	28.96
107001	B.DAR2 132.00	107002	T-ABAY2 132.00	0.035482	0.070505	0.01381	91	28.96
107001	B.DAR2 132.00	107006	DANGLA-132 132.00	0.0898	0.168	0.0329	115	69
107001	B.DAR2 132.00	107006	DANGLA-132 132.00	0.0898	0.168	0.0329	115	69
107003	PAWIE 132.00	107004	BELESSUGRFAC132.00	0.084562	0.158248	0.030993	115	65
107003	PAWIE 132.00	107004	BELESSUGRFAC132.00	0.084562	0.158248	0.030993	115	65
107003	PAWIE 132.00	107006	DANGLA-132 132.00	0.1416	0.2668	0.05131	115	109
107003	PAWIE 132.00	107006	DANGLA-132 132.00	0.1416	0.2668	0.05131	115	109
107006	DANGLA-132 132.00	107007	SHAWERA 132.00	0.1756	0.3287	0.06437	115	135
107008	DEDSSA 132.00	115010	NEKEMPTE 132.00	0.0848	0.1597	0.03071	115	65.25
108001	ADDIS-N 132.00	108015	MINILIK TS 132.00	0.002492	0.004058	0.000778	82	1.667
108002	DERBA-CEMENT132.00	108007	DERBA-TAP 132.00	0.0605	0.12105	0.02328	91	49.45
108002	DERBA-CEMENT132.00	108011	DERBA-TAP2 132.00	0.0605	0.12105	0.02328	91	49.45
108003	GEFERSA 132.00	108007	DERBA-TAP 132.00	0.075855	0.151771	0.02918	91	62
108003	GEFERSA 132.00	108011	DERBA-TAP2 132.00	0.075855	0.151771	0.02918	91	62
108003	GEFERSA 132.00	108015	MINILIK TS 132.00	0.014123	0.022998	0.004411	82	9.444
108003	GEFERSA 132.00	112005	KALITI1 132.00	0.037014	0.060275	0.01156	82	24.75
108003	GEFERSA 132.00	114003	SEBTA-TP 132.00	0.016122	0.026253	0.00503	82	10.78
108004	GHEDO 132.00	108005	GUDER 132.00	0.043829	0.082493	0.01598	89	33.99
108004	GHEDO 132.00	115010	NEKEMPTE 132.00	0.149436	0.281261	0.05449	89	115.89
108006	MUGER 132.00	108007	DERBA-TAP 132.00	0.022022	0.044062	0.00847	91	18
108006	MUGER 132.00	108011	DERBA-TAP2 132.00	0.022022	0.044062	0.00847	91	18
108009	FINCHA-II 132.00	115012	JARDEJARTE 132.00	0.1431	0.2678	0.05245	115	110
109001	ADIGRAT 132.00	109008	WUKRO-TP 132.00	0.072919	0.137245	0.02659	89	56.55

109002	ADWA 132.00	109004	MEKELE 132.00	0.150532	0.283324	0.05489	89	116.74
109004	MEKELE 132.00	109005	MESOBO 132.00	0.006525	0.012281	0.00238	89	5.06
109004	MEKELE 132.00	109005	MESOBO 132.00	0.0066	0.0123	0.00241	115	5.06
109004	MEKELE 132.00	109006	WIND-P 132.00	0.0195	0.0367	0.00706	115	15
109004	MEKELE 132.00	109008	WUKRO-TP 132.00	0.040025	0.075333	0.0146	89	31.04
109007	WUKRO 132.00	109008	WUKRO-TP 132.00	0.001506	0.002835	0.00055	89	1.17
109010	MEKELEII 132.00	109011	ABIADI 132.00	0.1236	0.2313	0.0453	115	95
110001	AWSH-7KL 132.00	110002	AMIBARA 132.00	0.0553	0.1043	0.02005	115	42.6
110001	AWSH-7KL 132.00	110003	DK290 TS 132.00	0.037677	0.07099	0.01365	115	29
110001	AWSH-7KL 132.00	111016	METEHARA-TS 132.00	0.040795	0.076865	0.01478	115	31.4
111001	A.TULU 132.00	111002	ASSELA 132.00	0.076217	0.124114	0.0238	82	50.96
111001	A.TULU 132.00	111019	ALUTO-II 132.00	0.039	0.0734	0.01412	115	30
111001	A.TULU 132.00	113009	S.SHEMEN 132.00	0.114899	0.187107	0.03588	82	76.83
111001	A.TULU 132.00	114001	BUTAJIRA 132.00	0.057234	0.114514	0.02202	91	46.78
111002	ASSELA 132.00	111003	AWASH2 132.00	0.07657	0.124689	0.02391	82	51.2
111003	AWASH2 132.00	111004	AWASH-3 132.00	0.002171	0.003512	0.00069	82	1.45
111003	AWASH2 132.00	111004	AWASH-3 132.00	0.002171	0.003512	0.00069	82	1.45
111003	AWASH2 132.00	111007	KOKA 132.00	0.037911	0.061736	0.01184	82	25.35
111003	AWASH2 132.00	111014	WONJPULP 132.00	0.026904	0.043812	0.0084	82	17.99
111005	ELALA-GD 132.00	111006	ELALA-TP 132.00	0.007328	0.011933	0.00229	82	4.9
111006	ELALA-TP 132.00	111007	KOKA 132.00	0.035578	0.057937	0.01111	82	23.79
111006	ELALA-TP 132.00	112013	INDODE 132.00	0.052	0.0979	0.01883	115	40
111007	KOKA 132.00	111011	NAZRETH2 132.00	0.017176	0.02797	0.00536	82	11.48
111007	KOKA 132.00	111014	WONJPULP 132.00	0.011007	0.017924	0.00344	82	7.36

111007	KOKA 132.00	111018	ABYSSINIAN 132.00	0.0193	0.0364	0.007	115	14.868
111007	KOKA 132.00	112004	DBZT2-TP 132.00	0.057652	0.093882	0.018	82	38.55
111008	M.WAKNA 132.00	111013	M.WK-YUG 132.00	0.006447	0.012135	0.00235	89	5
111008	M.WAKNA 132.00	111013	M.WK-YUG 132.00	0.006447	0.012135	0.00235	89	5
111008	M.WAKNA 132.00	113013	YADOT 132.00	0.122346	0.244792	0.04707	91	100
111009	METAHARA 132.00	111010	METEHARATAP 132.00	0	0.0001	0	82	0
111010	METEHARATAP 132.00	111011	NAZRETH2 132.00	0.13196	0.214889	0.0412	82	88.24
111010	METEHARATAP 132.00	111016	METEHARA-TS 132.00	0.001299	0.002448	0.000471	115	1
111012	WONJI-TP 132.00	111014	WONJPULP 132.00	0.000852	0.001388	0.00027	82	0.57
111013	M.WK-YUG 132.00	111020	GOBESA 132.00	0.0964	0.1816	0.03493	115	74.2
111013	M.WK-YUG 132.00	113009	S.SHEMEN 132.00	0.153691	0.28927	0.05604	89	119.19
111018	ABYSSINIAN 132.00	112011	AKAKI 2 132.00	0.0629	0.1184	0.02277	115	48.381
111020	GOBESA 132.00	111021	BALEROBE 132.00	0.0416	0.0783	0.01506	115	32
112001	A.CENTER 132.00	112005	KALITI1 132.00	0.02146	0.034947	0.0067	82	14.35
112002	ADS-II 132.00	112009	MEKANISA 132.00	0.002447	0.004896	0.00094	91	2
112002	ADS-II 132.00	112009	MEKANISA 132.00	0.0026	0.0049	0.00095	115	2
112003	DB-ZEIT2 132.00	112004	DBZT2-TP 132.00	0.000075	0.000122	0.00002	82	0.05
112004	DBZT2-TP 132.00	112011	AKAKI 2 132.00	0.0351	0.0661	0.01271	115	27
112005	KALITI1 132.00	112006	KALTI-N 132.00	0.012941	0.019726	0.003782	103	8.1
112005	KALITI1 132.00	112008	KLT.N-TP 132.00	0.002243	0.003653	0.0007	82	1.5
112005	KALITI1 132.00	112009	MEKANISA 132.00	0.024167	0.039355	0.00755	82	16.16
112005	KALITI1 132.00	112010	YESU 132.00	0.0104	0.0196	0.00377	115	8
112005	KALITI1 132.00	112011	AKAKI 2 132.00	0.0105	0.0161	0.00308	115	1
112005	KALITI1 132.00	112011	AKAKI 2 132.00	0.0105	0.0161	0.00308	115	1
112005	KALITI1 132.00	112017	KALITI TS 132.00	0.001104	0.006906	0.055942	100	5.81
112006	KALTI-N	112008	KLT.N-TP 132.00	0.000658	0.001072	0.00021	82	0.44

	132.00							
112007	KALTWO 132.00	112014	NEFASILK 132.00	0.00057	0.00356	0.02889	100	3
112007	KALTWO 132.00	112014	NEFASILK 132.00	0.00057	0.00356	0.02889	100	3
112007	KALTWO 132.00	112017	KALITI TS 132.00	0.00057	0.00356	0.02889	100	3
112008	KLT.N-TP 132.00	112016	KILINTO 132.00	0.0105	0.0161	0.00308	103	6.6
112009	MEKANISA 132.00	114003	SEBTA-TP 132.00	0.01168	0.01902	0.00365	82	7.81
112009	MEKANISA 132.00	114007	ADDIS-EFW 132.00	0.0091	0.0171	0.00329	115	7
112010	YESU 132.00	112011	AKAKI 2 132.00	0.0013	0.0024	0.00047	115	1
112011	AKAKI 2 132.00	112013	INDODE 132.00	0.0052	0.0098	0.00188	115	4
113001	A.MINCH 132.00	113012	W.SODO 132.00	0.140719	0.264855	0.05131	89	109.13
113002	ALABA 132.00	113008	HOSAINA 132.00	0.051063	0.096108	0.01862	89	39.6
113002	ALABA 132.00	113009	S.SHEMEN 132.00	0.081533	0.153457	0.02973	89	63.23
113002	ALABA 132.00	113012	W.SODO 132.00	0.079702	0.150011	0.02906	89	61.81
113003	AWASA 132.00	113009	S.SHEMEN 132.00	0.032303	0.052603	0.01009	82	21.6
113003	AWASA 132.00	113014	YIRGALEM 132.00	0.052477	0.085456	0.01639	82	35.09
113003	AWASA 132.00	113027	AWASA II 132.00	0.004487	0.007306	0.001401	82	3
113004	BOCU LUGUMA 132.00	113016	YABELO 132.00	0.13252	0.249688	0.048012	115	102
113005	DILLA 132.00	113007	HAGER MARIAY132.00	0.110112	0.220313	0.04236	91	90
113005	DILLA 132.00	113014	YIRGALEM 132.00	0.048939	0.097917	0.01883	91	40
113005	DILLA 132.00	113026	YIRGALEM II 132.00	0.04369	0.087415	0.01681	91	35.71
113007	HAGER MARIAY132.00	113016	YABELO 132.00	0.126024	0.237448	0.045658	115	97
113008	HOSAINA 132.00	115005	G.G OLD 132.00	0.091062	0.171393	0.03321	89	70.62
113009	S.SHEMEN 132.00	113027	AWASA II 132.00	0.028415	0.046271	0.008875	82	19
113010	SAWLA 132.00	113012	W.SODO 132.00	0.151709	0.303542	0.05837	91	124
113010	SAWLA 132.00	113017	KEY AFER 132.00	0.144213	0.271719	0.052248	115	111

113011	SHAKISO 132.00	113014	YIRGALEM 132.00	0.199216	0.324411	0.0622	82	133.21
113011	SHAKISO 132.00	113014	YIRGALEM 132.00	0.199216	0.324411	0.0622	82	133.21
113014	YIRGALEM 132.00	113026	YIRGALEM II 132.00	0.008564	0.017135	0.003295	91	7
113018	OMA-KURAZF1 132.00	113019	OMA-KURAZF2 132.00	0.0755	0.1412	0.02766	115	58
113018	OMA-KURAZF1 132.00	113019	OMA-KURAZF2 132.00	0.0755	0.1412	0.02766	115	58
113019	OMA-KURAZF2 132.00	113020	OMA-KURAZF3 132.00	0.026	0.0487	0.00954	115	20
113019	OMA-KURAZF2 132.00	113020	OMA-KURAZF3 132.00	0.026	0.0487	0.00954	115	20
113020	OMA-KURAZF3 132.00	113021	OMA-KURAZF4 132.00	0.0364	0.0682	0.01335	115	28
113020	OMA-KURAZF3 132.00	113021	OMA-KURAZF4 132.00	0.0364	0.0682	0.01335	115	28
113021	OMA-KURAZF4 132.00	113022	OMA-KURAZF5 132.00	0.0195	0.0367	0.00706	115	15
113022	OMA-KURAZF5 132.00	113023	OMA-KURAZF6 132.00	0.0221	0.0416	0.008	115	17
113024	BUEE 132.00	114001	BUTAJIRA 132.00	0.038977	0.073438	0.014121	115	30
114002	SEBATA 132.00	114003	SEBTA-TP 132.00	0.001496	0.002435	0.00047	82	1
114002	SEBATA 132.00	114004	ADDIS WEST 132.00	0.00133	0.00832	0.0674	100	7
114003	SEBTA-TP 132.00	114007	ADDIS-EFW 132.00	0.0088	0.0166	0.0032	115	6.8
114004	ADDIS WEST 132.00	114006	BLACK-LION 132.00	0.00095	0.00594	0.04814	100	5
114004	ADDIS WEST 132.00	114006	BLACK-LION 132.00	0.00114	0.00713	0.05777	100	6
115001	ABA 132.00	115008	JIMMA 132.00	0.057503	0.115052	0.02212	91	47
115002	AGARO 132.00	115003	B.BEDELE 132.00	0.104962	0.197555	0.03827	89	81.4
115002	AGARO 132.00	115008	JIMMA 132.00	0.044899	0.084507	0.01637	89	34.82
115003	B.BEDELE 132.00	115010	NEKEMPTE 132.00	0.141922	0.283958	0.0546	91	116
115004	BONGA 132.00	115008	JIMMA 132.00	0.125301	0.248984	0.04876	91	102.27
115004	BONGA 132.00	115008	JIMMA 132.00	0.125337	0.249057	0.04878	91	102.3

115004	BONGA 132.00	115009	MIZAN 132.00	0.108032	0.216151	0.04156	91	88.3
115005	G.G OLD 132.00	115006	G-GIBE-1 132.00	0.003353	0.00631	0.00122	89	2.6
115005	G.G OLD 132.00	115008	JIMMA 132.00	0.091964	0.173091	0.03353	89	71.32
115007	GIDA-AYANA 132.00	115010	NEKEMPTE 132.00	0.114503	0.229098	0.04405	91	93.59
115008	JIMMA 132.00	115013	ATANGO 132.00	0.1366	0.2556	0.05007	115	105
115009	MIZAN 132.00	115014	TUM 132.00	0.1951	0.3652	0.07152	115	150
202001	COTOBI-II 230.00	202002	SULULTA 230.00	0.0045	0.0126	0.04046	402	21
202001	COTOBI-II 230.00	202002	SULULTA 230.00	0.0045	0.0126	0.04046	402	21
202001	COTOBI-II 230.00	202004	BOLE-LEMI 230.00	0.001824	0.0051	0.016378	402	8.5
202001	COTOBI-II 230.00	202020	D.BEHRAN230 230.00	0.020245	0.061892	0.187103	318	100.412
202001	COTOBI-II 230.00	202021	COTOBI-I 230.00	0.0017	0.0048	0.01542	402	8
202001	COTOBI-II 230.00	202021	COTOBI-I 230.00	0.0017	0.0048	0.01542	402	8
202001	COTOBI-II 230.00	206001	COMBOL-II 230.00	0.057843	0.176833	0.53458	318	286.89
202001	COTOBI-II 230.00	212001	KALITI1 230.00	0.007058	0.020947	0.06727	318	34.91
202001	COTOBI-II 230.00	212001	KALITI1 230.00	0.007058	0.020947	0.06727	318	34.91
202002	SULULTA 230.00	202003	CHANCHO230 230.00	0.0032	0.009	0.0289	402	15
202002	SULULTA 230.00	202003	CHANCHO230 230.00	0.0032	0.009	0.0289	402	15
202002	SULULTA 230.00	202006	SHEGOLE 230.00	0.0017	0.0049	0.01491	402	8
202002	SULULTA 230.00	202006	SHEGOLE 230.00	0.0017	0.0049	0.01491	402	8
202002	SULULTA 230.00	208003	GEFERSA 230.00	0.003382	0.010038	0.03224	318	16.73
202002	SULULTA 230.00	208003	GEFERSA 230.00	0.003382	0.010038	0.03224	318	16.73
202004	BOLE-LEMI 230.00	212001	KALITI1 230.00	0.006525	0.018239	0.058577	402	30.4
202005	FITCHE 2 230.00	202008	GEBRE-GURCHA230.00	0.009849	0.028353	0.085714	402	46

202005	FITCHE 2 230.00	202008	GEBRE-GURCHA230.00	0.009849	0.028353	0.085714	402	46
202006	SHEGOLE 230.00	208003	GEFERSA 230.00	0.0019	0.0054	0.01627	402	8.73
202006	SHEGOLE 230.00	208003	GEFERSA 230.00	0.0019	0.0054	0.01627	402	8.73
202020	D.BEHRAN230 230.00	206001	COMBOL-II 230.00	0.037598	0.114941	0.347477	318	186.479
203001	ADIGALA 230.00	203004	HURSO 230.00	0.028047	0.080746	0.2441	402	131
203001	ADIGALA 230.00	203007	LASARAT 230.00	0.007708	0.02219	0.067081	402	36
203001	ADIGALA 230.00	203013	ADIGALA-TS 230.00	0.0018	0.0052	0.01657	402	8.6
203001	ADIGALA 230.00	203013	ADIGALA-TS 230.00	0.0018	0.0052	0.01657	402	8.6
203002	D.DAWA3 230.00	203004	HURSO 230.00	0.006117	0.017099	0.054916	402	28.5
203002	D.DAWA3 230.00	203004	HURSO 230.00	0.006117	0.017099	0.054916	402	28.5
203002	D.DAWA3 230.00	210001	AWSH-7KL 230.00	0.035593	0.158565	0.304992	353	205
203002	D.DAWA3 230.00	211001	KOKA 230.00	0.054881	0.260666	0.50138	274	337
203002	D.DAWA3 230.00	211007	NURAERA 230.00	0.0107	0.0308	0.09317	402	50
203003	DJIB-PK12 230.00	203007	LASARAT 230.00	0.025692	0.073965	0.223603	402	120
203003	DJIB-PK12 230.00	203012	SUBURBAN 230.00	0.0186	0.0536	0.16198	402	86.93
203004	HURSO 230.00	203005	HARAR IV 230.00	0.0105	0.0302	0.0913	402	49
203004	HURSO 230.00	203005	HARAR IV 230.00	0.0105	0.0302	0.0913	402	49
203004	HURSO 230.00	203006	DIRE-IND-230230.00	0.0047	0.0132	0.04239	402	22
203004	HURSO 230.00	203006	DIRE-IND-230230.00	0.0047	0.0132	0.04239	402	22
203004	HURSO 230.00	203010	MIESO 230.00	0.042071	0.117594	0.377668	402	196
203004	HURSO 230.00	203012	SUBURBAN 230.00	0.0458	0.1319	0.39863	402	213.93
203004	HURSO 230.00	211001	KOKA 230.00	0.075556	0.211189	0.678261	402	352
203004	HURSO 230.00	211005	NAZERET-ADAM230.00	0.062945	0.181215	0.547828	402	294
203006	DIRE-IND-230230.00	203008	LONNIS 230.00	0.003434	0.009599	0.03083	402	16
203006	DIRE-IND-	203011	SHI-KUL-230 230.00	0.0118	0.033	0.10598	402	55

	230230.00							
203007	LASARAT 230.00	203014	AYISHAWIND 230.00	0.0021	0.006	0.01927	402	10
203007	LASARAT 230.00	203014	AYISHAWIND 230.00	0.0021	0.006	0.01927	402	10
203008	LONNIS 230.00	203011	SHI-KUL-230 230.00	0.009015	0.025199	0.080929	402	42
203010	MIESO 230.00	211001	KOKA 230.00	0.025114	0.070196	0.225445	402	117
204001	GAMBELA2 230.00	204002	METU 230.00	0.029974	0.086293	0.26087	402	140
204002	METU 230.00	215001	BEDELLE 230.00	0.018245	0.055777	0.16862	318	90.49
206001	COMBOL-II 230.00	206002	TOSAMETAL 230.00	0.0021	0.006	0.01927	402	10
206001	COMBOL-II 230.00	206002	TOSAMETAL 230.00	0.0021	0.006	0.01927	402	10
206001	COMBOL-II 230.00	206003	COMBOLIND 230.00	0.003	0.0084	0.02698	402	14
206001	COMBOL-II 230.00	206003	COMBOLIND 230.00	0.003	0.0084	0.02698	402	14
206001	COMBOL-II 230.00	206004	WOLDIA 230.00	0.0193	0.054	0.17342	402	90
206001	COMBOL-II 230.00	206004	WOLDIA 230.00	0.0193	0.054	0.17342	402	90
206001	COMBOL-II 230.00	206007	DESSIE 230.00	0.0047	0.0132	0.04239	402	22
206001	COMBOL-II 230.00	206007	DESSIE 230.00	0.0047	0.0132	0.04239	402	22
206001	COMBOL-II 230.00	209001	ALAMATA 230.00	0.034126	0.101275	0.32526	318	168.8
206001	COMBOL-II 230.00	209001	ALAMATA 230.00	0.034126	0.101275	0.32526	318	168.8
206001	COMBOL-II 230.00	210003	SEMERA 230.00	0.034276	0.104784	0.31677	318	170
206004	WOLDIA 230.00	206005	SUN-HI-GUL 230.00	0.0155	0.0432	0.13874	1973	72
206004	WOLDIA 230.00	206005	SUN-HI-GUL 230.00	0.0155	0.0432	0.13874	1973	72
206004	WOLDIA 230.00	206007	DESSIE 230.00	0.0189	0.0528	0.16957	402	88
206004	WOLDIA 230.00	206007	DESSIE 230.00	0.0189	0.0528	0.16957	402	88
206004	WOLDIA 230.00	209001	ALAMATA 230.00	0.0144	0.0402	0.1291	402	67
206004	WOLDIA	209001	ALAMATA 230.00	0.0144	0.0402	0.1291	402	67

	230.00							
206005	SUN-HI-GUL 230.00	206006	TERU 230.00	0.0107	0.03	0.09634	1973	50
206005	SUN-HI-GUL 230.00	206006	TERU 230.00	0.0107	0.03	0.09634	1973	50
207001	B.DAR2 230.00	207005	GONDAR2 230.00	0.029325	0.084425	0.255224	402	136.97
207001	B.DAR2 230.00	207005	GONDAR2 230.00	0.029325	0.084425	0.255224	402	136.97
207001	B.DAR2 230.00	207007	MOTA 230.00	0.012781	0.066429	0.12006	280	83
207001	B.DAR2 230.00	207008	N.MEW TP 230.00	0.027501	0.084074	0.25416	318	136.4
207001	B.DAR2 230.00	207011	WORETA 230.00	0.01199	0.034517	0.104348	402	56
207002	DB-MRKOS 230.00	207007	MOTA 230.00	0.017209	0.089447	0.16166	280	111.76
207002	DB-MRKOS 230.00	207010	DEJEN 230.00	0.009206	0.026504	0.080124	402	43
207002	DB-MRKOS 230.00	208001	FINCHA 230.00	0.014652	0.076154	0.13763	280	95.15
207003	GASHENA 230.00	207004	GASHE-TA 230.00	0.000202	0.000616	0.00186	318	1
207004	GASHE-TA 230.00	207008	N.MEW TP 230.00	0.020626	0.063056	0.19062	318	102.3
207004	GASHE-TA 230.00	209001	ALAMATA 230.00	0.020626	0.063056	0.19062	318	102.3
207005	GONDAR2 230.00	207006	METEMA 230.00	0.033358	0.098995	0.31793	318	165
207005	GONDAR2 230.00	207006	METEMA 230.00	0.035326	0.101702	0.307454	402	165
207005	GONDAR2 230.00	209011	DANSHA 230.00	0.0246	0.0709	0.21429	402	115
207006	METEMA 230.00	207013	SUDAN-GADARE230.00	0.0343	0.096	0.3083	402	160
207006	METEMA 230.00	207013	SUDAN-GADARE230.00	0.0343	0.096	0.3083	402	160
207008	N.MEW TP 230.00	207009	N.MEWCHA 230.00	0.000202	0.000616	0.00186	318	1
207008	N.MEW TP 230.00	207011	WORETA 230.00	0.017826	0.05132	0.155143	402	83.26
207013	SUDAN-GADARE230.00	207014	SUDAN-RABAK 230.00	0.050586	0.228355	0.43378	402	400
207013	SUDAN-GADARE230.00	207014	SUDAN-RABAK 230.00	0.050586	0.228355	0.43378	402	400
208001	FINCHA 230.00	208002	FINCHA-II 230.00	0.001673	0.005116	0.01547	318	8.3
208001	FINCHA 230.00	208004	GHEDO 230.00	0.010041	0.053852	0.09704	284	67.19

208002	FINCHA-II 230.00	208004	GHEDO 230.00	0.014058	0.042977	0.12992	318	69.72
208002	FINCHA-II 230.00	208004	GHEDO 230.00	0.014923	0.042962	0.129876	402	69.7
208002	FINCHA-II 230.00	208005	NESHE 230.00	0.005897	0.018027	0.0545	318	29.25
208003	GEFERSA 230.00	208004	GHEDO 230.00	0.020486	0.106479	0.19244	280	133.04
208003	GEFERSA 230.00	208004	GHEDO 230.00	0.028548	0.079796	0.256275	402	133
208003	GEFERSA 230.00	208004	GHEDO 230.00	0.028548	0.079796	0.256275	402	133
208003	GEFERSA 230.00	208006	A.ALEM 230.00	0.007371	0.035277	0.066746	363	45
208003	GEFERSA 230.00	208007	GINCHI 230.00	0.013523	0.037798	0.121393	402	63
208003	GEFERSA 230.00	208009	TORHAYILOCH 230.00	0.006886	0.012974	0.002495	115	5.3
208004	GHEDO 230.00	208006	A.ALEM 230.00	0.01425	0.068203	0.129042	363	87
208004	GHEDO 230.00	208007	GINCHI 230.00	0.015455	0.043198	0.138735	402	72
208004	GHEDO 230.00	215004	G-GIBE-OLD 230.00	0.021099	0.102687	0.1886	274	130
208006	A.ALEM 230.00	208008	MUGERII 230.00	0.015	0.042	0.13488	402	70
208009	TORHAYILOCH 230.00	214001	SEBATA-1 230.00	0.006886	0.012974	0.002495	115	5.3
209001	ALAMATA 230.00	209004	MEKELE 230.00	0.028534	0.084677	0.27195	318	141.14
209001	ALAMATA 230.00	209007	MEHONI 230.00	0.0077	0.0222	0.06708	402	36
209001	ALAMATA 230.00	209013	ASHEGODA WF 230.00	0.0265	0.0762	0.23048	402	123.69
209002	ENDASILA 230.00	209003	HUMERA 230.00	0.046434	0.137799	0.44256	318	229.68
209002	ENDASILA 230.00	209006	TEKEZE 230.00	0.032245	0.09569	0.30732	318	159.49
209002	ENDASILA 230.00	209006	TEKEZE 230.00	0.032245	0.09569	0.30732	318	159.49
209002	ENDASILA 230.00	209010	WELKAYT 230.00	0.034343	0.095995	0.308301	402	160
209003	HUMERA 230.00	209010	WELKAYT 230.00	0.034129	0.095395	0.306374	402	159

209003	HUMERA 230.00	209011	DANSHA 230.00	0.0219	0.0631	0.19062	402	102.3
209004	MEKELE 230.00	209006	TEKEZE 230.00	0.021228	0.062997	0.20232	318	105
209004	MEKELE 230.00	209006	TEKEZE 230.00	0.021228	0.062997	0.20232	318	105
209004	MEKELE 230.00	209007	MEHONI 230.00	0.020982	0.060405	0.182609	402	98
209004	MEKELE 230.00	209008	DALOL 230.00	0.0343	0.096	0.3083	402	160
209004	MEKELE 230.00	209008	DALOL 230.00	0.0343	0.096	0.3083	402	160
209004	MEKELE 230.00	209009	MEKELEPVC 230.00	0.0009	0.0024	0.00771	402	4
209004	MEKELE 230.00	209009	MEKELEPVC 230.00	0.0009	0.0024	0.00771	402	4
209004	MEKELE 230.00	209013	ASHEGODA WF 230.00	0.0041	0.0117	0.0354	402	19
210001	AWSH-7KL 230.00	210006	MELKASEDI 230.00	0.005995	0.017259	0.052174	402	28
210001	AWSH-7KL 230.00	210006	MELKASEDI 230.00	0.005995	0.017259	0.052174	402	28
210001	AWSH-7KL 230.00	211001	KOKA 230.00	0.022453	0.100028	0.192398	353	129.32
210001	AWSH-7KL 230.00	211007	NURAERA 230.00	0.031	0.0894	0.27019	402	145
210002	DITCHETO 230.00	210003	SEMERA 230.00	0.011089	0.033901	0.10248	318	55
210003	SEMERA 230.00	210004	TENDAHO 230.00	0.0043	0.0123	0.03727	402	20
211001	KOKA 230.00	211002	M-WAKNA 230.00	0.029689	0.127801	0.24166	257	163.86
211001	KOKA 230.00	211002	M-WAKNA 230.00	0.029689	0.127801	0.24166	257	163.86
211001	KOKA 230.00	211005	NAZERET-ADAM230.00	0.004496	0.012944	0.039131	402	21
211001	KOKA 230.00	211022	ADAM-IIWIND 230.00	0.0022	0.0065	0.01957	402	10.5
211001	KOKA 230.00	213001	DUKEM TAP 2 230.00	0.005374	0.025525	0.0491	274	33
211001	KOKA 230.00	215002	DUKEM TAP 1 230.00	0.005374	0.025525	0.0491	274	33
211002	M-WAKNA 230.00	213002	RAMO 230.00	0.047736	0.133429	0.428524	402	222.39
211002	M-WAKNA 230.00	213006	GINIR 230.00	0.034042	0.098004	0.296274	402	159
211002	M-WAKNA 230.00	213010	AWASA-230 230.00	0.0225	0.063	0.20238	402	105

211002	M-WAKNA 230.00	213010	AWASA-230 230.00	0.0225	0.063	0.20238	402	105
211003	MODJO3230 230.00	212003	DB-ZEIT3230 230.00	0.0017	0.0048	0.01542	402	8
212001	KALITI1 230.00	212005	AKAKI2-230 230.00	0.000773	0.00312	0.005899	331	4
212001	KALITI1 230.00	212005	AKAKI2-230 230.00	0.000773	0.00312	0.005899	331	4
212001	KALITI1 230.00	214001	SEBATA-1 230.00	0.002314	0.011264	0.02069	274	14.26
212001	KALITI1 230.00	214008	H.TANNERY 230.00	0.0024	0.0068	0.0205	402	11
212002	DUKEM230 230.00	212003	DB-ZEIT3230 230.00	0.0017	0.0048	0.01542	402	8
212002	DUKEM230 230.00	212003	DB-ZEIT3230 230.00	0.0017	0.0048	0.01542	402	8
212005	AKAKI2-230 230.00	213001	DUKEM TAP 2 230.00	0.01237	0.049916	0.094387	331	64
212005	AKAKI2-230 230.00	215002	DUKEM TAP 1 230.00	0.01237	0.049916	0.094387	331	64
213002	RAMO 230.00	213003	GODE 230.00	0.063526	0.177565	0.570273	402	295.96
213002	RAMO 230.00	213003	GODE 230.00	0.063526	0.177565	0.570273	402	295.96
213002	RAMO 230.00	213006	GINIR 230.00	0.016271	0.046845	0.141615	402	76
213004	ALABA 230.00	213005	HOSAINA 230.00	0.008435	0.024285	0.073416	402	39.4
213005	HOSAINA 230.00	214003	WOLKITE 230.00	0.019119	0.055043	0.166398	402	89.3
213008	OMA-KURAZF1 230.00	213009	W.SODO230 230.00	0.0526	0.147	0.47209	402	245
213008	OMA-KURAZF1 230.00	213009	W.SODO230 230.00	0.0526	0.147	0.47209	402	245
213010	AWASA-230 230.00	213011	YIRGALEM-II 230.00	0.008571	0.024	0.077074	318	40
213010	AWASA-230 230.00	213011	YIRGALEM-II 230.00	0.008571	0.024	0.077074	318	40
213010	AWASA-230 230.00	213012	YIRGALEMI 230.00	0.0075	0.021	0.06744	402	35
213011	YIRGALEM-II 230.00	213012	YIRGALEMI 230.00	0.0026	0.0072	0.02312	402	12
213011	YIRGALEM-II 230.00	213012	YIRGALEMI 230.00	0.0026	0.0072	0.02312	402	12
214001	SEBATA-1 230.00	214002	SEBETA-2 230.00	0.002321	0.011775	0.02228	280	15.02
214001	SEBATA-1 230.00	214002	SEBETA-2 230.00	0.002321	0.011775	0.02228	280	15.02
214001	SEBATA-1	214004	WOLISO 230.00	0.02141	0.061638	0.186336	402	100

	230.00							
214001	SEBATA-1 230.00	214006	ADDIS-EFW 230.00	0.0011	0.003	0.00963	402	5
214001	SEBATA-1 230.00	214006	ADDIS-EFW 230.00	0.0011	0.003	0.00963	402	5
214001	SEBATA-1 230.00	214008	H.TANNERY 230.00	0.0016	0.0045	0.01353	402	7.26
214003	WOLKITE 230.00	214004	WOLISO 230.00	0.009035	0.026011	0.078634	402	42.2
214003	WOLKITE 230.00	215004	G-GIBE-OLD 230.00	0.010779	0.056025	0.10125	280	70
215001	BEDELLE 230.00	215006	AGARO 230.00	0.017494	0.048897	0.157041	402	81.5
215001	BEDELLE 230.00	215006	AGARO 230.00	0.017494	0.048897	0.157041	402	81.5
215002	DUKEM TAP 1 230.00	215007	EAST INDUSTR230.00	0	0.0001	0	0	0
215003	G-GIBE-1 230.00	215004	G-GIBE-OLD 230.00	0.000814	0.003867	0.00744	274	5
215003	G-GIBE-1 230.00	215004	G-GIBE-OLD 230.00	0.000814	0.003867	0.00744	274	5
215003	G-GIBE-1 230.00	215005	JIMMA 230.00	0.014081	0.039358	0.126403	402	65.6
215003	G-GIBE-1 230.00	215005	JIMMA 230.00	0.014081	0.039358	0.126403	402	65.6
215005	JIMMA 230.00	215006	AGARO 230.00	0.008307	0.023219	0.07457	402	38.7
215005	JIMMA 230.00	215006	AGARO 230.00	0.008307	0.023219	0.07457	402	38.7
402001	SULULTA 400.00	402003	GEBRE-GURCHA400.00	0.002	0.0271	0.7483	1341	131.5
402001	SULULTA 400.00	402003	GEBRE-GURCHA400.00	0.0027	0.0213	0.9377	1973	131.5
402001	SULULTA 400.00	407003	D-MARKOS 400.00	0.003335	0.04436	1.22684	1341	215.6
402001	SULULTA 400.00	407003	D-MARKOS 400.00	0.0045	0.035	1.54022	1973	216
402001	SULULTA 400.00	414002	HOLETA-400 400.00	0.0006	0.005	0.22105	1973	31
402001	SULULTA 400.00	414002	HOLETA-400 400.00	0.0006	0.005	0.22105	1973	31
402002	AKAKI2400 400.00	412001	DB-ZEIT2400 400.00	0.0006	0.0049	0.21392	1973	30
402002	AKAKI2400 400.00	412001	DB-ZEIT2400 400.00	0.0006	0.0049	0.21392	1973	30
402002	AKAKI2400 400.00	413001	W.SODO400 400.00	0.0055	0.0432	1.90389	1342	267
402002	AKAKI2400	413001	W.SODO400 400.00	0.0055	0.0432	1.90389	1342	267

	400.00							
402002	AKAKI2400 400.00	414001	SEBETA-2 400.00	0.0007	0.0057	0.22078	1973	33
402002	AKAKI2400 400.00	414002	HOLETA-400 400.00	0.001	0.0079	0.349	1973	49
402002	AKAKI2400 400.00	414002	HOLETA-400 400.00	0.001	0.0079	0.349	1973	49
402003	GEBRE-GURCHA400.00	407003	D-MARKOS 400.00	0.0014	0.018	0.4979	1341	87.5
402003	GEBRE-GURCHA400.00	407003	D-MARKOS 400.00	0.0018	0.0142	0.6239	1973	87.5
403001	HURSO400 400.00	411001	AWASH7-400 400.00	0.0039	0.0302	1.32987	1973	186.5
403001	HURSO400 400.00	411001	AWASH7-400 400.00	0.0039	0.0302	1.32987	1973	186.5
406001	WOLDIA 400.00	407001	BAHIRDAR-II 400.00	0.0056	0.0435	1.91815	1973	269
406001	WOLDIA 400.00	407001	BAHIRDAR-II 400.00	0.0056	0.0435	1.91815	1973	269
407001	BAHIRDAR-II 400.00	407002	BELES 400.00	0.000958	0.012159	0.37713	1341	62.84
407001	BAHIRDAR-II 400.00	407002	BELES 400.00	0.000958	0.012159	0.37713	1341	62.84
407001	BAHIRDAR-II 400.00	407003	D-MARKOS 400.00	0.002997	0.03986	1.10239	1341	193.73
407001	BAHIRDAR-II 400.00	407004	GRAN RENAIS 400.00	0.005033	0.041797	1.605239	1973	240
407002	BELES 400.00	407004	GRAN RENAIS 400.00	0.0044	0.0366	1.40458	1973	210
411001	AWASH7-400 400.00	412001	DB-ZEIT2400 400.00	0.0035	0.027	1.18726	1973	166.5
411001	AWASH7-400 400.00	412001	DB-ZEIT2400 400.00	0.0035	0.027	1.18726	1973	166.5
413001	W.SODO400 400.00	413002	YIRGALEMII 400.00	0.00179	0.014697	0.56384	1973	84.3
413001	W.SODO400 400.00	413002	YIRGALEMII 400.00	0.00179	0.014697	0.56384	1973	84.3
413001	W.SODO400 400.00	415001	G-GIBE-2 400.00	0.0025	0.0207	0.79593	1341	119
413001	W.SODO400 400.00	415003	GIBE-III 400.00	0.001	0.0081	0.35653	1973	50
413001	W.SODO400 400.00	415003	GIBE-III 400.00	0.001	0.0081	0.35653	1973	50
413001	W.SODO400 400.00	415004	G-GIBE3 400.00	0.001	0.0081	0.35653	1342	50

413001	W.SODO400 400.00	415004	G-GIBE3 400.00	0.001	0.0081	0.35653	1342	50
413001	W.SODO400 400.00	415004	G-GIBE3 400.00	0.0011	0.0083	0.36366	1342	51
413002	YIRGALEMII 400.00	413003	GENDAWAIII 400.00	0.005638	0.043914	1.932408	1973	271
413002	YIRGALEMII 400.00	413003	GENDAWAIII 400.00	0.005638	0.043914	1.932408	1973	271
414001	SEBETA-2 400.00	414002	HOLETA-400 400.00	0.0004	0.0029	0.12835	1973	18
414001	SEBETA-2 400.00	414002	HOLETA-400 400.00	0.0004	0.0029	0.12385	1973	18
414001	SEBETA-2 400.00	415001	G-GIBE-2 400.00	0.002839	0.037756	1.04419	1341	183.5
415001	G-GIBE-2 400.00	415002	GIGIBE-OLD 400.00	0.000431	0.005737	0.15868	1341	27.89

APPENDIX C: Load Flow Analysis

Table C-1 Peak load flow

X-- AREA -- X	GENE-RATION	FROM IND GENERATION	TO IND MOTORS	TO LOAD	TO BUS SHUNT	GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	TO TIE LINES	TO TIES LOADS
1	0	0	0	12.2	0	0	0.1	0	0.2	-12.6	-120.6
ASOSA	0	0	0	1.6	7.8	0	0	14	0.9	3.5	-34.2
2	0	0	0	256.2	0	0	0.8	0	8	-265	-218.7
EASTERN A.A.	0	0	0	82.1	0	0	2.3	345.2	62.3	198.5	202.6
3	0	0	0	145.3	0.2	0	0.6	0	9.6	-155.8	-86.4

EASTERN	0	0	0	66.5	55	0	51.5	322.6	36	113.7	150.5
4	0	0	0	16	0.1	0	0.1	0	0.9	-17.1	-17
GAMBELA	0	0	0	7.7	50.5	0	0.1	44.1	3.2	-17.4	-17.4
5	0	0	0	12.4	0	0	0	0	0.3	-12.8	-12.8
JIJIGA	0	0	0	6.8	0	0	0	3.9	1.9	-4.8	-4.8
6	0	0	0	71.3	0.1	0	0.2	0	3.4	-75	-75
NORTH EASTER	0	0	0	27.1	14.8	0	0.5	42.4	13.5	-13.4	-13.4
7	3434	0	0	3279.1	0.7	0	1.1	0	33.7	119.4	104.4
NORTH WESTER	1477	0	0	1568.8	271	0	62.8	589.3	170.7	-7.1	-14.4
8	189.9	0	0	205.6	0	0	0.9	0	12	-28.6	-29.8
NORTHERN A.A	23.5	0	0	82.6	0	0	2.4	112.8	72.1	-20.7	-21.7
9	183.3	0	0	203.8	0.2	0	0.8	0	7.7	-29.2	-29.2
NORTHERN	43.8	0	0	96.4	65.9	0	14.3	183.9	64.8	-13.7	-13.7
10	0	0	0	13.9	0	0	0.2	0	1.8	-15.9	-15.9
SEMERA	0	0	0	6.7	0	0	15.5	74.1	7.7	44.1	44.1
11	181.8	0	0	153.5	0.1	0	1	0	8.3	18.9	18.8
SOUTH EASTER	89.5	0	0	79.6	17.9	0	4.8	90.1	49.7	27.6	27.6
12	3.3	0	0	449	0.2	0	0.8	0	27	-473.7	-458.5
SOUTHERN	0.4	0	0	188.6	87.7	0	3.2	211.2	269.7	-337.6	-330.2

A.A											
13	0	0	0	158.8	0.5	0	0.6	0	34.5	-194.4	-209
SOUTHERN	0	0	0	72.2	173	0	1.3	233.7	113.5	-126.2	-133.3
14	0	0	0	218.9	0	0	1	0	15.1	-235	-220
WESTERN A.A.	0	0	0	84.3	-256.2	0	3.5	209.6	164.3	213.8	221
15	1478.6	0	0	84	0.1	0	1.1	0	16.5	1376.9	1376.5
WESTERN	444.8	0	0	40.3	45.4	0	3.4	215.3	631.5	-60.3	-60.5
20	0	0	0	0	0	0	0	0	0	0	-6.7
	0	0	0	0	0	0	0	0	0	0	-2.3
COLUMN	5470.9	0	0	5280.3	2.2	0	9.4	0	179	0	0
TOTALS	2078.9	0	0	2411.3	532.8	0	165.5	2692.4	1661.7	0	0

Table C-2 Generator VAR limits

X-- NAME --X	BAS KV	MW	MVAR	QMAX	QMIN	VSCHED	V ACTUAL	X-- NAME --X	BAS KV	MVA BASE	AREA SWING
ABA SAMUEL	6.3	3.3	0.4	0.4	-0.2	1	0.9815	ABA SAMUEL	45	5.4	1
AWASH2-1	10.5	6.4	12.9	12.9	-16	1	0.9475	AWASH2	132	20	2
AWASH3-1	10.5	6.4	12.9	12.9	-16	1	0.9483	AWASH-3	132	20	2
KOKA1	10.5	6.1	13.1	13.1	-12	1	0.9547	KOKA	132	18	2
AWASH2-2	10.5	6.4	12.9	12.9	-16	1	0.9475	AWASH2	132	20	2
AWASH3-2	10.5	6.4	12.9	12.9	-16	1	0.9483	AWASH-3	132	20	2

KOKA2	10.5	6.1	13.1	13.1	-12	1	0.9547	KOKA	132	18	2
ADAMA WF-I	33	26.7	17	17	-17	1	0.9594	ADAM-I WIND	132	53.7	2
ADAMA WF-II	33	87.5	0	49.7	0	1	1.0039	ADAMA II WF	230	161.2	2
NESHE-1	13.8	44.6	-13.7	18.1	-13.7	1	1.0271	NESHE	230	53	4
NESHE-2	13.8	44.6	-13.7	18.1	-13.7	1	1.0271	NESHE	230	53	4
G-GIBE1-1	13.8	57.1	18.7	18.7	-18.7	1.02	1.0094	GI GIBE-1	230	73	8
G-GIBE1-2	13.8	14.3	38.4	38.4	-50.9	1.02	1.0094	GI GIBE-1	230	73	8
G-GIBE1-3	13.8	57.1	18.7	18.7	-18.7	1.02	1.0094	GI GIBE-1	230	73	8
ASHEGODA-WF	33	8.3	58.4	58.4	0	1	0.998	ASHEGODA WF	230	188.5	9

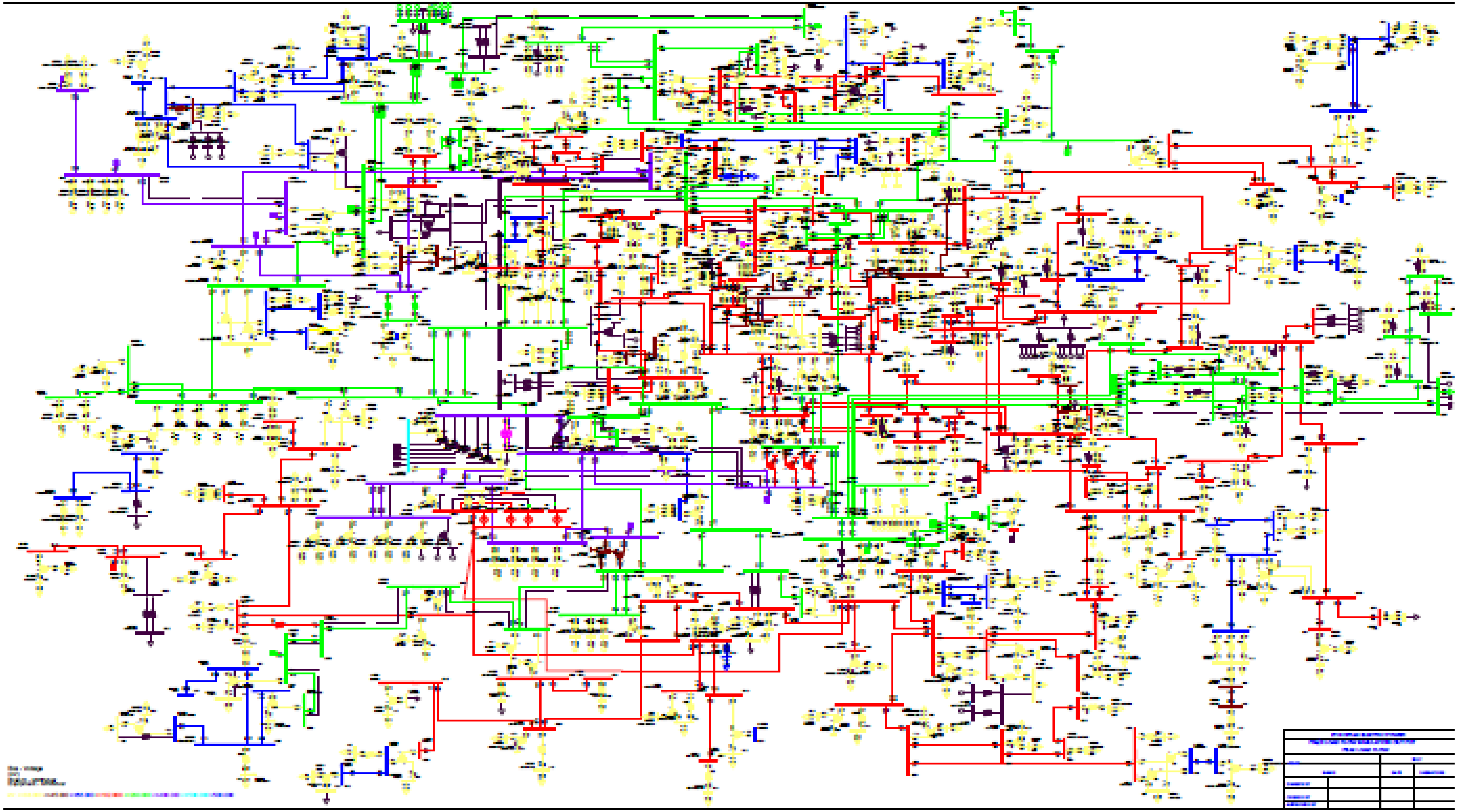

Figure C-1 PSS/E single line model peak load of 2017 Ethiopian Transmission Grid

APPENDIX D: General Network Diagram of EEP

Table D-1 Buses with voltage less than their normal low limit

BUS#	X-- NAME --X	BASKV	V(PU)	VLIMIT	BUS#	X-- NAME --X	BASKV	V(PU)	VLIMIT
102001	ADD EAST-II	132	0.944	0.95	102002	B.WGN-TP	132	0.9468	0.95
102003	COTEBEI-I	132	0.9497	0.95	102004	DEBRE BERHAN	132	0.9413	0.95
102006	WERGENU	132	0.9391	0.95	102010	ADDIS-E1	132	0.9492	0.95
105001	JIJIGA I	132	0.9198	0.95	106004	SHOWA-ROBIT	132	0.9449	0.95
108001	ADDIS-NORTH	132	0.9407	0.95	108002	DERBA-CEMENT	132	0.6832	0.95
108006	MUGER	132	0.789	0.95	108007	DERBA-TAP	132	0.7944	0.95
108015	MINILIK TS	132	0.9451	0.95	108016	HABESHA CEM	132	0.886	0.95
108017	HABESHA TP	132	0.886	0.9	109001	ADIGRAT	132	0.9133	0.95
109002	ADWA	132	0.8713	0.95	109005	MESOBO	132	0.9494	0.95
109007	WUKRO	132	0.9371	0.95	109008	WUKRO-TP	132	0.9373	0.95
109020	ABIADI MB TP	132	0.8948	0.95	109021	ABIADI MB	132	0.8932	0.95
111001	ADAMI TULU	132	0.9024	0.95	111002	ASSELA	132	0.9266	0.95
111027	WON SUG TP	132	0.9474	0.95	111028	WON SUG	132	0.9473	0.95
112001	ADDIS CENTER	132	0.9253	0.95	112002	GOFA	132	0.9456	0.95
112007	KALITI TWO	132	0.9493	0.95	112009	MEKANISA	132	0.9472	0.95
112014	NEFASILK	132	0.9487	0.95	112019	DANGOTE TP	132	0.791	0.95
113003	AWASA	132	0.8537	0.95	113004	BOCULUGUMA	132	0.7851	0.95
113005	DILLA	132	0.8036	0.95	113007	HAGER MARIAM	132	0.7929	0.95
113009	SHASHEMENE	132	0.8962	0.95	113011	SHAKISO	132	0.7711	0.95
113014	YIRGALEM	132	0.819	0.95	113029	AWASA MOBILE	132	0.9353	0.95

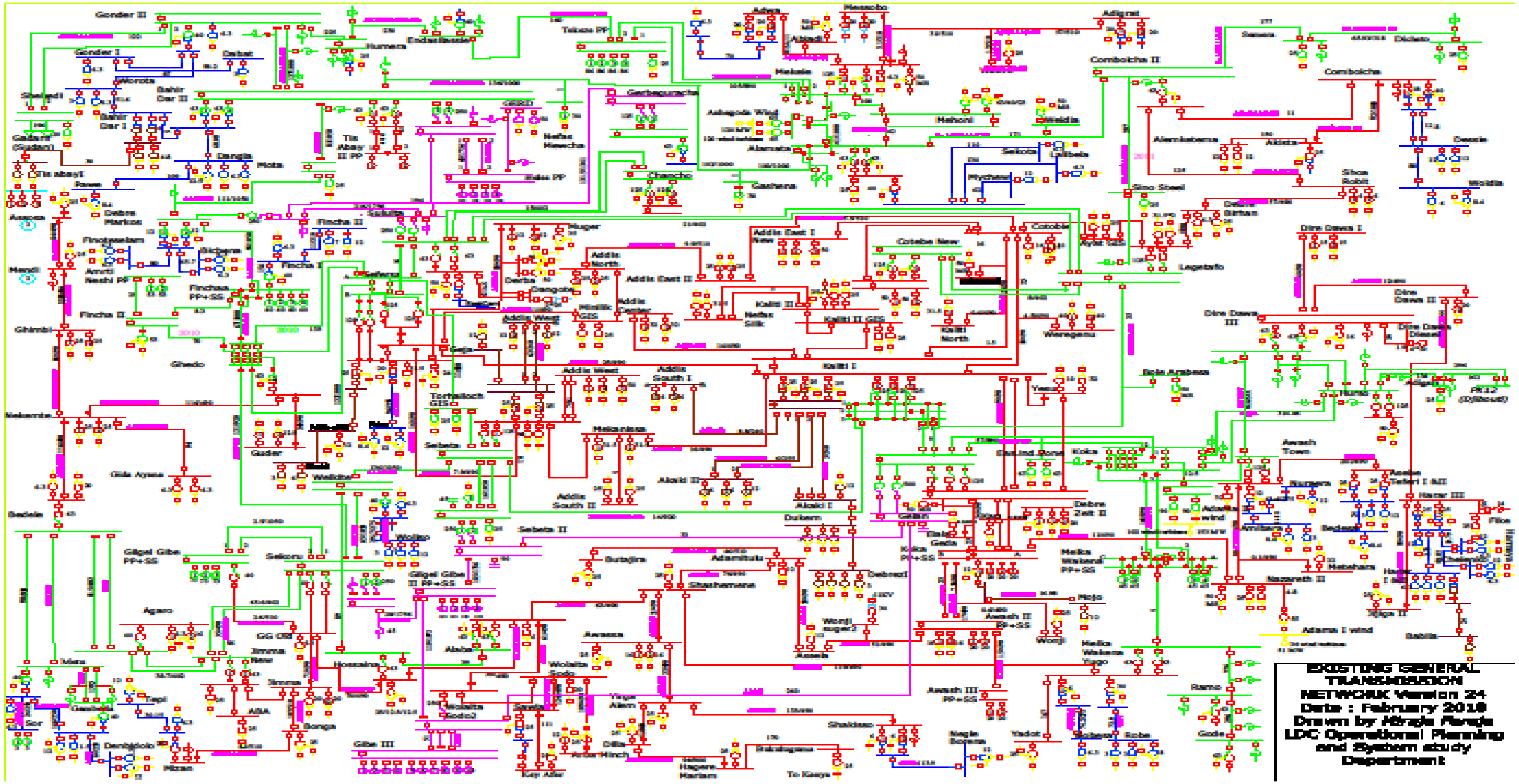

Figure D-1 General Network Diagram