Sudan University of Science & Technology

College of Engineering

Electrical Engineering Department

INTELLIGENT LOAD SHEDDING

الفصل الذكي للأحمال

A Project Submitted in Partial fulfillment for the Requirements of the Degree of B.Sc. (Honors) in Electronics Engineering

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الآية

بسم الله الرحمن الرحيم

قال تعالي:

"وَقُلِ اعْمَلُواْ فَسَيَرَى اللهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ وَسَتُرَدُّونَ إِلَى عَالِمِ الْغَيْبِ وَالْشَهَادَةِ فَيُنَبِئُكُمْ بِمَا كُنتُمْ تَعْلَمُونَ"

سورة التوبة الآية(105)

Dedication

This project is dedicated to…

Our beloved **parents** for their love, endless support, and encouragement

Our **teachers** who guided through this path of learning toward success

And to those who accompanied us in the path of **friendship.**

Acknowledgment

We thank gad **(ALLAH)** for giving me the endurance and perseverance to complete this work.

We are truly indebted and thankful to them supervisor **Dr. Mohammed Osman Hassan** for his suggestions criticism and guidance throughout the thesis work.

We could not complete this work without the continuous support our families; we would like to give special thanks to our families.

We are thankful to our friends; for his constructive comments and supporting in pursuing this work.

Abstract

This study is conducted to test the possibility of using intelligent load shedding at Sudanese power grid and aimed to know the effect of intelligent load shedding at the power grid stability especially at the condition of loss of generation.

At this study analytic hierarchical process (AHP) method had been used to determine the weight factors of each load at Sudanese power grid loads, then load flow had been applied to Sudanese power grid at three cases:

Normal condition, loss of generation and load shedding condition .after applying Intelligent Load Shedding (ILS) at losing of generation four loads had been shaded: ALMUGRAN (MUG), New ALHASAHISA (NHAS),Old ALHASAHISA (OHAS) and ALGINAD (GND). After applying ILS power system grid over all performance had improved. The study recommended to implement the real time function and the important of loads should be estimated by experts of engineers and designers.

المستخلص

هذه الدراسة أجريت لاختبار إمكانية استخدام نظام الفصل الذكي لأحمال في شبكة النقل السودانية وتهدف لمعرفة تأثير الفصل الذكي لأحمال في استقرارية الشبكة خصوصا في حالة فقد جزء من للكهرباء التوليد.

في هذه الدراسة تستخدم طريقة عملية التدرج التحليلي لإيجاد الأوزان لأحمال (أولوية الأحمال) في شبكة النقل السودانية للكهرباء، تم إجراء دراسة انسياب للحمولة في الشبكة لثلاث حالات :
في الحالة الطبيعية ،فقد جزء من التوليد وفي حالة فصل بعض الأحمال من الشبكة ، تم فصل الأحمال في حالة فقدان التوليد في محطة قري الحرارية وهي المقرن – الحصاحيصا الجديدة ، الحصاحيصا القديمة والجنيد .بعد الفصل تحسنت إستقرارية الشبكة إعتبرت هذه النتائج مقبولة وتوفر دليلا لإمكانية الاستفادة من هذه الدراسة .أوصت الدراسة بتطبيق دالة الزمن والربط مع الشبكة وأهمية الأحمال يجب أن تقدر بواسطة المهندسين الخبراء والمصممين.

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LIST OF ABBREVIATION

ILS	Intelligent Load Shedding
AHP	Analytic Hierarchical Process
NFP	Network Flow programming
EP	Evolutionary programming
MUG	Almugran
NHAS1	New Hasahesa
OHAS1	Old Ahasahesa
GND1	Agnaeed
DON	Dongla
SHG	Alshgraa
MWT	Marawy Tawon
KSL	Kasla
NHLF	New Hlfa
LOM	Local Market
SHN	Shendy
FAO	Alfao
GAD	Giad
FUL	Alfula
SHK	Alshook
AFR	Afra
MAR	Almarengan
MRK	Almrkhyat
GDF	Algdareef

HAG	Alhag Abd Allah
KUK	Kuko
BNT	Bant
SOB	Soba
IBA	Id Babkeer
MHD	Almahdiya
SNG	Snga
SNJ	Sinar Jenction
OMD	Omdurman
RBK	Rabk
KLX	Kilo Ashara
OBD	Alobid
KHE	Khartoum East
IZB	Alizba
IZG	Izergab
FAR	Faroog
ATB	Atbra
RNK	Alrank
HWT	Alhawata
TND	Tndlty
UMR	Um Rwabah
BAG	Albageer
MAN	Almnagil
MIN	Mina Ashreef
DEB	Aldaba
FRZ	Free Zone

WHL	Wadi Hlfa
ORBK	Old Rabk
SNP	Sinar Plant
MWP	Marawey Plant
JAS	Aljabel Station
GAM	Algumyya
KAB	Kaboshya
KHN	Khartoum North
ARO	Aroma
ROS	Alroseers
GRB	Algrba
HUD	Alhuda
WWA	Wawa

LIST OF SYMPOLES

Z	Impedance
Y	Admittance
I	Bus Current
V	Bus Voltage
P	Active Power
Q	Reactive Power
δ	Power Angle
H	inertial constant
D	Load damping coefficient
K_m	Frequency control loop gain
F_H	High - pressure re - warmed turbines ’ power portion
T_R	Re warming time constant
P_m	Mechanical power of the turbine
P_a	Accelerator’ s power
ΔW	Speed change

CHAPTER ONE
INTRODUCTION

1.1 Background

The security and stability of electrical power systems have always been one of the central and fundamental issues of concern in network planning and operation. Serving users of electricity is the duty of power systems that generate, transmit, and distribute electrical energy. Therefore, system operation, network growth and expansion are highly user dependent and the system should be able to satisfy their needs and requirements. Central requirements include reliability, quality of energy, and continued load capacity. Network designers and operation managers should continuously pay attention to these requirements and take the necessary steps to fulfill them and maintain the desired qualities. Over load is one of the main factors that affect the power system stability and it can be reduced through some control strategy such as a generation rescheduling scheme, obtaining power support from a neighboring utility as well as optimal load shedding. In the particular case of power shortage, load shedding cannot be avoided.

In general, load shedding can be defined as the amount of load that must almost instantly be removed from a power system to keep the remaining Portion of the system operational. This load reduction is in response to a System disturbance (and consequent possible additional disturbances) that results in a generation deficiency condition or network overloading situation.

Common disturbances that can cause these conditions to occur include transmission line or transformer faults, loss of generation, switching errors, and lightning strikes.

1.2 Problem Statement

When all available controls are unable to maintain the security of system operation during a disturbance or contingency as over loading or loss of generation optimal load shedding will be used as the last resort to make the loss of blackout minimum.

A main problem of the intelligent load shedding is how to choose load to shed conveniently and quickly. There is a technical problem of finding the right level and location of the load to shed.

1.3 Project Objectives

The main objective of this project is to investigation of the intelligent load shedding to be implements at the network through MATLAB and ETAB software. To achieve this objective:-

1. Shed the minimum amount of load to maintain system stability and nominal frequency.
2. Shed the optimal combinations of load breakers with complete know ledge of system dependencies.
3. Recognize different system patterns in order to predict system response for different disturbances.
4. Utilize a built - in knowledge base trainable by user - defined cases.
5. Adaptive self - learning and automatic training of system knowledge base due to system changes.
6. Make fast, correct, and reliable decisions on load shedding priority based on the actual loading status of each breaker.

1.4 Methodology

This first introduces the traditional load shedding methods such as under frequency or under voltage load shedding and then studies optimal power system load shedding methods. These include intelligent load shedding, distributed interruptible load shedding, Everett optimization, analytic hierarchical process (AHP) and network flow programming (NFP).Application of analytic hierarchical process (AHP).

MATLAB program used to calculate AHP weighting factors and ETAP simulation program had been used to implement the above objectives and to show clearly the working function of intelligent load shedding.

1.5 Project Outlines

This research consists of an abstract and five chapters, Chapter one represent the introduction that contents of background, research problem, research objective and research methodology. Chapter two is represent the types, parts and uses of the intelligent load shedding with briefly look to conventional load shedding. Chapter three show the tools and expectation of the intelligent load shedding. Chapter four will include the using of ETAP program with example show the working of intelligent load shedding using real data from the national Sudanese electrical company and the result will be discussed. Finally the conclusion and recommendations are presented in chapter Five. And reference in the last.

CHAPTER TWO
CONVENTIONAL LOAD SHEDDING

2.1 Sudan network load shedding

The used method is conventional load shedding which is only depend on frequency and mainly there are three types of conventional load shedding no matter any method used that conventional load shedding is basically a last resort backup measure. As such, it will be called on to operate only when a highly improbable, potentially catastrophic disturbance occurs. Therefore, if the possibility of complete system collapse is to be avoided during such a disturbance [4].

2.1.1 Under Frequency Controlled Load Shedding

Any part of a power system will begin to deteriorate if there is an excess of load over available generation. The prime movers and their associated generators begin to slow downs they attempt to carry the excess load. Tie lines to other parts of the system, or to other power systems across a power pool, attempt to supply the excess load. This combination of events can cause the tie lines to open from overload or the various parts of the systems to separate due to power swings and resulting instability. The result may be one or more electrically isolated islands in which load may exceed the available generation further, the drop in frequency may endanger generation itself.

While a hydroelectric plant is relatively unaffected by even a ten percent reduction in frequency, a thermal generating plant is quite sensitive to even a five percent reduction. Power output of a thermal plant depends to a great extent on its motor-driven auxiliaries such as boiler feed-water pumps coal pulverizing and feeding equipment, and draft fans. As system frequency decreases, the power output to the auxiliaries begins to fall off rapidly which in turn further reduces the energy input to the turbine and consequently to the generator. The situation thus has a cascading effect with a loss of frequency leading to a loss of power which can cause the frequency to deteriorate further and the entire plant is soon in serious trouble. An addition alma or concern is the possible damage to the steam turbines due to prolonged operation at reduced frequency during this severe overload condition. To prevent the complete collapse of the island, under frequency relays are used to automatically drop load in accordance with a predetermined schedule to balance the load to the available generation in the affected area. Such action must be taken promptly and must be of sufficient magnitude to conserve essential load and enable the remainder of the system to recover from the under frequency condition. Also, by preventing a major shut down, restoration of the entire system to normal operation is greatly facilitated and expedited.

It is generally recognized that the sudden loss of generating capacity on a system will be accompanied by a decrease in system frequency. The frequency will not suddenly deviate affixed amount from normal but rather will decay at some rate. The initial rate of frequency decay will depend solely on the amount of overload and on the inertia of the system. However, as the system frequency decreases, the torque of the remaining system generation will tend to increase, the load torque will tend to decrease and the overall effect will be a reduction in the rate of frequency decay. Assuming no governor action, the damping effect produced by changes in generator and load torques will eventually cause the system frequency to settle-out at some value below normal. If governor action is considered, And if the remaining generators have some pick-up capability, the rate of the frequency decay will be reduced further and the frequency will settle out at some higher value.

In either case the system would be left at some reduced frequency that may cause a further decrease in generating capacity before any remedial action could be taken. The variation of system frequency during such a disturbance is not a smooth rate of decay but rather is oscillatory in nature because of the interaction of the interconnected generators. Moreover, the rate of decay and the period of oscillation may differ appreciably across the system. In general, it is not possible to analytically determine the frequency oscillations that can occur on a system of appreciable size during such a disturbance. The nature of these oscillations can only be determined from detailed computer studies of the system. However, it is possible to determine, and predict with reasonable accuracy, the average rate off frequency decay that can occur for different magnitudes of generation deficiencies.

Voltage level can also affect the system active power loading. It is usually assumed that a one percent change in voltage will produce a corresponding one percent change in active load power. During severe system emergencies, which result in insufficient generation to meet load, an automatic load shedding program throughout the affected area can prevent a total system collapse. It also helps to achieve fast restoration of all affected loads. The application of under frequency relays in substations throughout the load area, preset to drop specific percent magnitudes of load at predetermined low system frequency values, provides the simplest automatic load shedding program. Relay settings can be developed to drop the minimum load to arrest system frequency decay at a safe operating level. Additional under frequency relays can also be applied to initiate a safe and orderly separation or shutdown if the emergency is beyond the capabilities of the load shedding program [4].

Load shedding by frequency relays is the most commonly used method for controlling the frequency of power networks within set limits and maintaining network stability under critical conditions. In the conventional load – shedding methods, when frequency drops below the operational plan ’ s set point, the frequency relays of the system issue commands to disconnect parts of the electrical power load in a stepwise manner, thereby preventing further frequency drop and its consequential effects. The reason that frequency is the main criterion of system quality and security is as follows:

1. A global variable of interconnected networks that has the same value in
    a. all parts of the network
2. An indicator of the balance between supply and demand
3. A critically important factor for the smooth operation of all users and particularly manufacturing and industries one of the main problems of all interconnected networks is a total black out because of frequency drop as a consequence of some power station failure or transmission line breakage.

Presently, in the power generation and transmission systems of the world, the most appropriate way of preventing a total or partial blackout that is triggered by frequency drop is quick and automatic load shedding. To study situations of imbalance between power supply and demand, and the resulting frequency variations under the circumstances of severe and major disorders, a simplified model of the steady state for systems that consist mainly of thermal units is used , which is shown in Figure 2.1 The expression of the model is as follows:

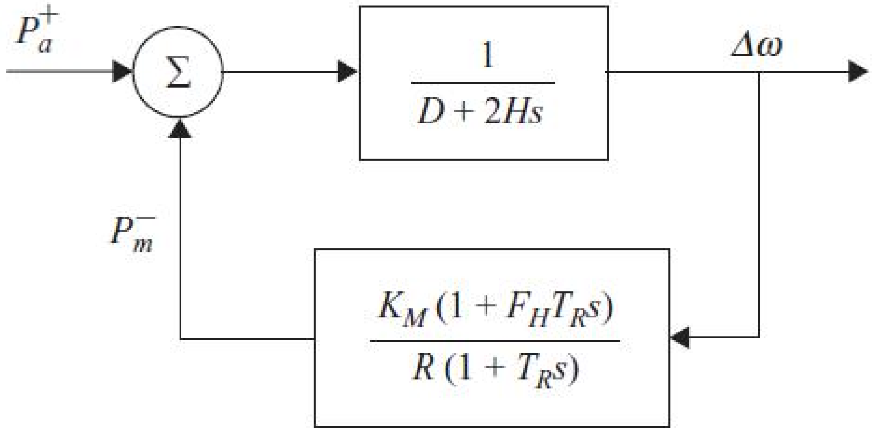

Figure 2.1: Steady - state frequency - response model

$$\Delta w = \frac{Pa}{D}\left(1 - e^{\frac{-D}{2H}T}\right) \quad (2.1)$$

Where

H: System's inertial constant

D: Load damping coefficient

K_m: Frequency control loop gain

F_H: High - pressure re - warmed turbines' power portion

T_R: Rearming time constant

P_m: Mechanical power of the turbine (per unit)

P_a: Accelerator's power

ΔW: Speed change (per unit)

Equation (2.1) models the system at the initial conditions of major disorders when the governor's effect is lifted off because during the first seconds of the disorder, due to governor s response delay and its operating time constant, it cannot play a role in prevention of the frequency drop .According to equation (2.1), the main factors and parameters that control the behavior of frequency and overloading are the amount of over load inland the *D* and *H* parameters. The effect of these two parameters should be definitely considered in any load - shedding scheme. The load damping coefficient (D) is an effective parameter that represents the relation between the load and the frequency. It cannot be ignored in planning for load - shedding schemes. In planning for load shedding, the load damping coefficient is normally expressed per unit as shown in the following formula:

$$D=\frac{f\times\Delta p}{p\times\Delta f} \tag{2.2}$$

The value of *D* varies from 0 to 7 and is to be determined once for each System and used in all cases of planning. The latest studies have shown *D*= 3.3 for the sample network.

The effect of *D* on the frequency drop gradient is quite visible as an increase in *D* causes a decrease in the frequency drop gradient. For any specified overloading, systems with a higher value of *D* will have a higher stability and the final system frequency will be stabilized at a higher level. Figure (2.2) clearly shows the effect of *D* on the frequency drop curve .In commonly used stepwise methods, the load - shedding scheme has little relation to the degree of overload. Any overload triggers the same strategy of load shedding, as the degree of overload does not determine the number or quantity of the load shedding.

This kind of scheme greatly simplifies the task of harmonizing the relays and the steps of load shedding, as simple calculations and a process of trial and error would suffice. It is one of the obvious advantages of this kind of scheme. Once the steps of load shedding are specified, if at any step the frequency continues to drop (with regard to the specified delay times), then the next step will be automatically activated until the frequency stops dropping. In such strategies, increasing the number of steps can increase the costs and allow a more precise harmony and a minimized blackout area. Never the less, in almost all countries, only three to five steps are planned, with rare cases of more steps. In such strategies or plans, the first step of load shedding is regulated in such a way that with any frequency drop below the set point, this step is activated to operate within its specific time delay.

The time duration for frequency to drop from normal to below the set point is not taken into consideration, despite the fact that we know that the gradient of frequency drop is directly proportional to the amount of overload and severity of the case; therefore, it can be a basis to decide on whether only one step is adequate [2].

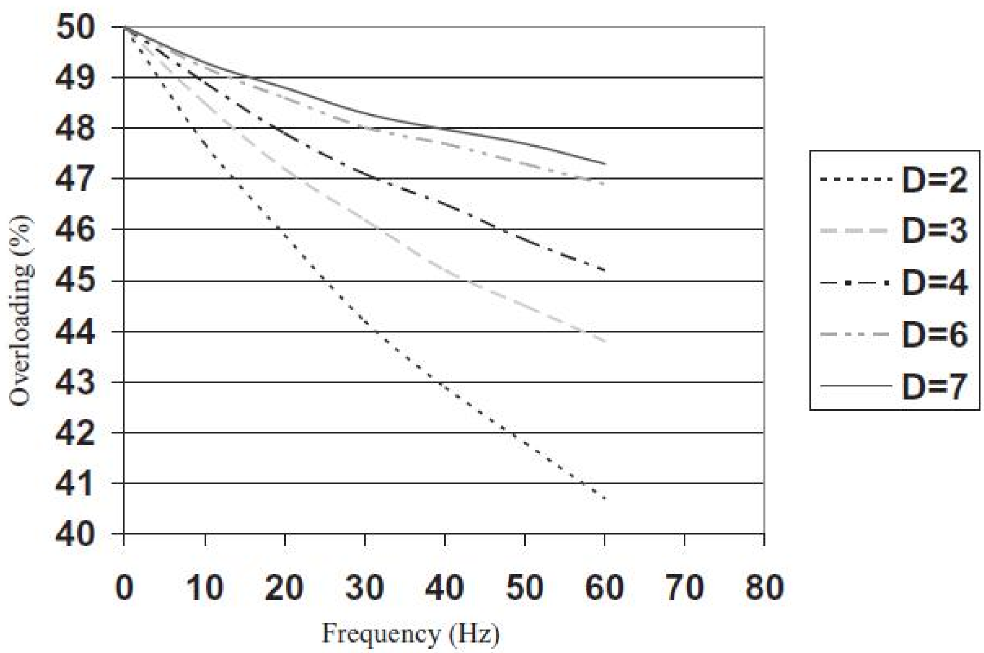

Figure2.2: The effect of load damping coefficient on the frequency drop curve

But for the following drawback under frequency method could failed

1. Response time is slow.
2. Incorrect / excessive load shedding.
3. Lack of knowledge in the analysis to shed the load [2].

2.1.2 Under Voltage Controlled Load Shedding

A voltage collapse of part of the electrical system is an indication that for the existing conditions and contingencies, some portion of the combined generation and transmission system has been operated beyond its capability. Voltage collapse can also be a symptom of a much larger problem, and when the system starts to collapse, there is a real danger that the localized problem will cascade into wider areas. The purpose of proper system planning and operating philosophies is for the system to function reliably, and failing that, to contain the impacts of disturbances to localized areas. Voltage collapse or uncontrolled loss of load or cascading may occur, for example, when sending sources are far enough removed from an area that the voltage at its loads experiences a significant drop, especially during outage contingencies. System studies are needed to determine which systems are the potential candidates for a suitable UVLS scheme.

It is most useful in a slow-decaying voltage system with the under-voltage relay time delay settings typically between 3 to 10 seconds. When overloads occur on long transmission lines in conjunction with a significant local voltage dip, then the effect of UVLS action would also be to alleviate such overloads. Among all the potential uses of UVLS, it is usually not helpful for mitigating transient instability. The relay time delay to trip is normally set long enough to avoid false tripping and, hence load tripping will not occur fast enough to mitigate a transient stability event. UVLS is usually not helpful for mitigating local network facility overloading.

The under-voltage trip threshold must be set low enough (again to avoid false tripping) that the UVLS relays would not pick up for most system conditions under which the typical facility would overload. In today’s stressed transmission systems coupled with declining reactive power reserves, UVLS can be a low cost alternative to constructing new transmission lines or new generation to maintain system security. While new transmission lines and new generation projects are needed to meet the system load and provide long-term stability, such projects typically take about 3-10 years to complete. UVLS can be used as an interim measure until these projects are completed [1].

But for the following drawback under voltage controlled method could failed:

1. More loads could be shedded.
2. System modification could be costly.
3. Delay time at clearing fault [3].

2.1.3 Breaker Inter Lock Load Shedding

Even though its execution is fast, it has some drawbacks, listed below:

1. Load shedding based on worst.
2. More loads are shed than required.
3. Only one stage of load shedding.
4. System modifications are costly [3].

CHAPTER THREE

INTELLIGENT LOAD SHEDDING

3.1 Introduction

The "intelligent load shedding" is a means enabling to improve power system stability, by providing a real time adapted load control and load shedding, in situations where the power system otherwise would go unstable. The work with intelligent load shedding in this work package results in various technical principles of dedicated algorithms. These algorithms intend to bring a support tool for the operating system during critical situations. The main aspects are evaluating the right amount and location of power response for a given disturbance, and evaluating the right time response expected in order to comply with inacceptable stability recover. This time response is a main object in order to define appropriate ICT network enabling such a reliable implementation.

The last blackouts show that the existing load shedding is not sufficient enough for some critical EPS situations. A main aspect is the need of an appropriate response in power and in time with fast remote supervision and control. The aim of the load shedding is keeping the power system stability, i.e. keep the bulk power or transmission system energized together with as much of the load as possible. In our case of intelligent load shedding, the loads shed are assumed to be distributed among the feeders: chosen loads among the network are disconnected. Before removing loads or just after this kind of action, a way to contribute to the stability during critical situations on the EPS is maintaining a smooth load relief: the variations of power exchanges are limited in magnitude and in time (except for means dedicated for fast power balance) in order to avoid too much stresses on the voltage control (frequency and magnitude).Additionally various critical preventing actions may be taken in order to contribute to support the system facing a temporary disturbance: for instance maintaining a low voltage level (but still normal) on the distribution network helps to limit the injected current by the transmission network. These three kinds of approach need to be coordinated between them in order to be enough efficient and coherent. It involves specific market incentives and associated ICT requirements.

The existing load shedding system is based on frequency or magnitude voltage thresholds and involves opening of complete and distributed MV feeders (the sending-end circuit breaker on 10kV or 20kV is ordered to open). The magnitude of power disconnection is not really known, leading to possible instability increase. The priority of load shedding is done feeder by feeder, what is not convenient with safety and security purposes. A best way is to define priority between the loads (for instance elevators may involve safety aspects) and warn the remaining supplied loads of the critical situation being faced (for instance the elevators may be stopped at the next floor with doors blocked open if critical warning is maintained).

The traditional view on shedding system is for large stability purpose at transmission level. In the future and in addition another kind of problem may be solved also by local shedding distributed in the feeders: voltage and current constraints occurring inside the distribution feeders. This need will appear when the dispersed local production DR will be taken into account in the reduced design or reduced reinforcement of the lines and the cables. So the ILS functions and goals are larger than stability on transmission, they will deal also with the energy management and security assessment of the whole system on distribution and transmission. What is needed is to proceed step by step recovering the previous action on transmission security, and then to integrate the other valuable functions (enough profitable for the different actors of the local market) gradually.

The traditional LS for transmission includes two main protection systems based on relays for detecting under frequency and relays for detecting under voltage situations. A first part of the document presents the existing LS with these two ways of detection and action. A second part deals with the concept of intelligent load shedding and of smooth load relief, and with the associated needed market and ICT system. The main kinds of investigated actions are presented.

A third part deals with the general problem of EPS large oscillation mitigation. At the same time ILS may contribute to the mitigation by appropriate fast loads oscillations but also take benefit of the existing damping system (the efficiency and the accuracy of the required distributed LS depends on the capacity of the system to face a given magnitude of oscillation, magnitude linked to transient global power imbalance). Moreover the right identification of the large disturbance occurring on the transmission network is of prime interest: the best action on DR or on controlled loads facing power oscillations or global power unbalance are different [1].

3.2 Main Concepts of Intelligent Load Shedding

Above existing conventional load shedding methods will no longer proper method that could estimate a stable shedding operation that Conventional load shedding systems that rely solely on frequency measuring systems cannot be programmed with the knowledge gained by the power system designers. The system engineer must perform numerous system studies that include all of the conceivable system operating conditions and configurations to correctly design the power system. Unfortunately, the engineer' knowledge of the system that is gained through the studies is not utilized fully. Additionally, most data and study results are simply lost. This unavailability of information for future changes and enhancement of the system will significantly reduce the protection system performance. The state - of - the - art load - shedding system uses real - time system wide data acquisition that continually updates a computer - based real - time system model. This system produces the optimum solution for system preservation by shedding only the necessary amount of load and is called intelligent load shedding ILS [5].

This system must have the following capabilities:

1. Able to map a very complex and nonlinear power system with a limited number of data collection points to a finite space.
2. Automatically remember the system configuration, operation conditions as load is added or removed, and the system response to disturbances with all of the system configurations.
3. Recognize different system patterns in order to predict system response for different disturbances.
4. Utilize a built - in knowledge base trainable by user - defined cases.
5. Adaptive self - learning and automatic training of system knowledge base due to system changes.
6. Make fast, correct, and reliable decisions on load shedding priority based on the actual loading status of each breaker.
7. Shed the minimum amount of load to maintain system stability an nominal frequency.
8. Shed the optimal combinations of load breakers with complete knowledge of system dependencies.

In addition to having the above list of capabilities, the ILS system must have a dynamic knowledge base. For the knowledge base to be effective, it must be able to capture the key system parameters that have a direct impact on the system frequency response following disturbances. These parameters include:

1. Power exchanged between the system and the grid both before and after disturbance.
2. Generation available before and after disturbances.
3. On - site generator dynamics.
4. Updated status and actual loading of each shed able load.
5. The dynamic characteristics of the system loads. This includes rotating machines, constant impedance loads, constant current loads, constant power loads, frequency - dependent loads, or other types of loads.

3.2.1 Function Block Diagram of the ILS

In Figure 3.1 the system knowledge base is pre trained by using carefully selected input and output databases from offline system studies and simulations. System dynamic responses, including frequency variation, are among the outputs of the knowledge base.

The trained knowledge base runs in the background of an advanced monitoring system, which constantly monitors all of the system operating conditions. The network models and the knowledge base provide power system topology, connection information, and electric properties of the system component for ILS. The disturbance list is prepared for all pre specified system disturbances (triggers). Based on the input data and system updates, the knowledge base periodically sends requests to the ILS computation engine to update the load shedding tables, thus ensuring that the optimum load will be shed when a disturbance occur. The load shedding tables in turn are downloaded to the distributed controls that are located close to each sheddable load. When a disturbance occurs, fast load - shedding action can be taken [2].

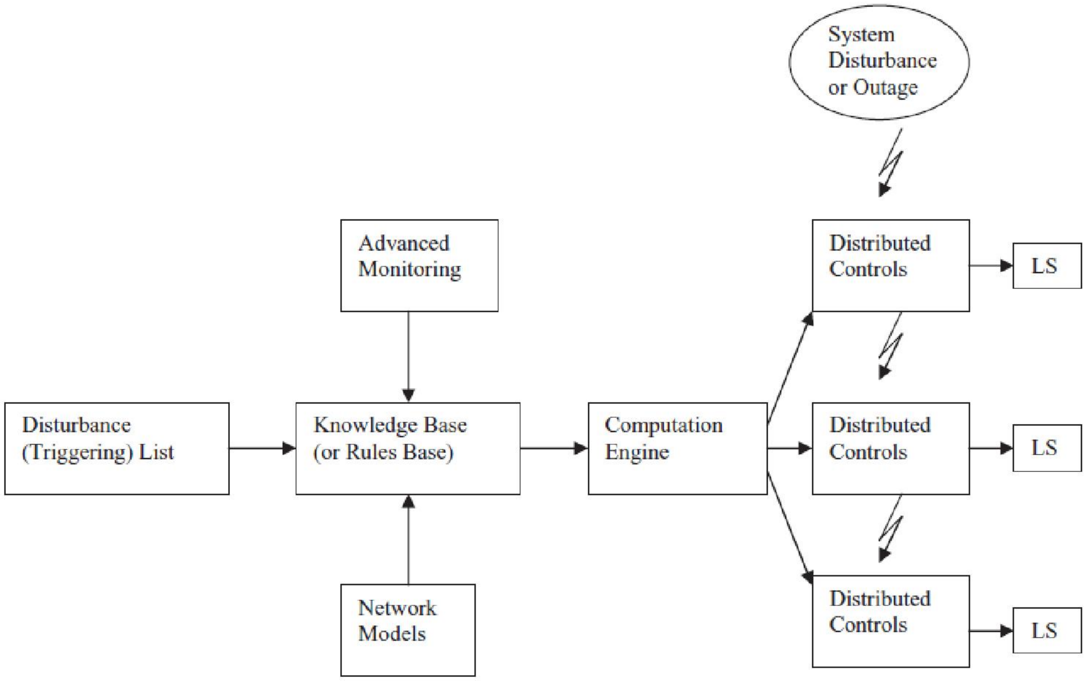

Figure 3.1: Function block diagram of the ILS scheme

3.2.2 Formulation of Optimal Load Shedding

In a competitive resource allocation environment, buy/sell decision support systems are needed to find economical ways to serve critical loads with limited sources under different uncertainties. Therefore, a value - driven load – shedding approach is proposed for this purpose. The mathematical model of load shedding is expressed as follows.

3.3 ILS with Network Constrain Method Using AHP

There are many method of intelligent load shedding, distributed interruptible load shedding, Everett optimization, analytic hierarchical process (AHP), and network flow programming (NFP).the AHP method will be taken in details at this chapter.

3.3.1 Calculation of Weighting Factors by AHP

The weighting factors that express the value of the load and it priority
It represents the root of this method. AHP Algorithmic a decision making approach it presents the alternatives and criteria, evaluates trade - off, and performs a synthesis to arrive at a final decision. AHP is especially appropriate for cases that involve both qualitative and quantitative analysis.

The steps of the AHP algorithm may be written as follows:

Step 1: Set up a hierarchy model.

Step 2: Form a judgment matrix the value of elements in the judgment matrix reflects the user's knowledge about the relative importance between every pair of factors.

Step 3: Calculate the maximal Eigen value and the corresponding eigenvector of the judgment matrix.

Step 4: Hierarchy ranking and consistency check of results.

Calculation step overview**:**

(1) Multiply all elements of each row in the judgment matrix

$$M_i = \Pi_i X_{ij} \; ; i = 1 \dots n; j = 1 \dots n \qquad (3.1)$$

Where

n: The dimension of the judgment matrix *A*

X_{ij}: An element in the judgment matrix *A*

(2) Calculate the *nth* root of M_i

$$W_i^* = \sqrt[n]{M} \; ; i=1 \dots n \qquad (3.2)$$

We can obtain the vector

$$W^* = [w_1^*, w_2^* \dots w_n^*]^T \qquad (3.3)$$

(3) Normalize the vector w^*

$$W_i=\frac{w_i^*}{\sum_{j=1}^{n} w_j^*}\ ;\ i=1\ldots n \tag{3.4}$$

In this way, we obtain the eigenvector of the judgment matrix *A*, that is,

$$W= [w_1, w_2,\ldots,w_n]^T \tag{3.5}$$

3.3.2 Principles of AHP Calculation

Computing the weight factors for the following judgment matrix**:**

$$A=\begin{bmatrix} 1 & \frac{1}{5} & \frac{1}{3} \\ 5 & 1 & 3 \\ 3 & \frac{1}{3} & 1 \end{bmatrix} \tag{3.6}$$

The calculation steps are as follows:

1. Multiply all elements of each row in the judgment matrix

$$M1=1\times\frac{1}{5}\times\frac{1}{3}= 0.067 \tag{3.7}$$

$$M2=5\times1\times3=15 \tag{3.8}$$

$$M3=3*(1/3)*1=1 \tag{3.9}$$

2. Calculate the *n* th root of M_i

$$W_1=\sqrt[3]{M_1} = \sqrt[3]{0.067}= 0.405 \tag{3.10}$$

$$W_2=\sqrt[3]{M_2}= \sqrt[3]{15}= 2.446 \tag{3.11}$$

$$W_3=\sqrt[3]{M_3} = \sqrt[3]{1}= 1 \tag{3.12}$$

Now

$$W = [W_1 \; W_2 \; W_3]^T. \quad (3.13)$$

$$W = [0.405 \; 2.446 \; 1]^T. \quad (3.14)$$

3. Normalize the vector W^*:

$$\sum_{j=1}^{3} W_j^* = 0.405 + 2.446 + 1 = 3.871 \quad (3.15)$$

$$W_i = \frac{w_i}{\sum_{j=1}^{3} w_j} \quad (3.16)$$

$$W_1 = 0.105 \quad (3.17)$$

$$W_2 = 0.637 \quad (3.18)$$

$$W_3 = 0.258 \quad (3.19)$$

The eigenvector of the judgment matrix *A* is obtained, that is,

$$W = [W_1 \; W_2 \; W_3] = [0.105 \; 0.637 \; 0.258] \quad (3.20)$$

From above method it is very difficult to compute exactly the weighting factor of each load in the reason is that the relative importance of these loads is not the same, which is related to the power market operation conditions. According to the principle of AHP described latterly, the weighting factors of the loads can be determined through the ranking computation of a judgment matrix, which reflects the judgment and comparison of a series of pair of factors. The hierarchical model for computing the load weighting factors is shown in Figure (2.2), in which *PI* is the performance index of load center *k* .The judgment matrix *A -LD* of the load shedding problem can be written as follows:

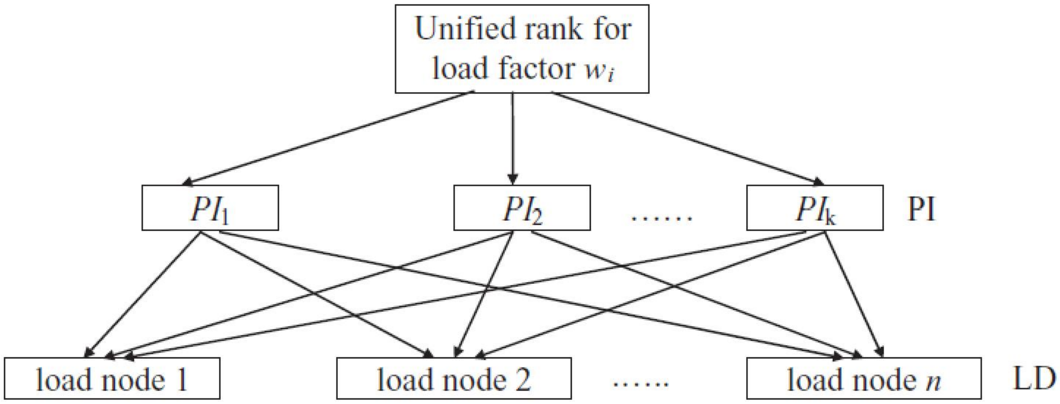

Figure 3.2: Hierarchy model of load weighting factor rank

$$\boldsymbol{A\text{-}LD} = \begin{bmatrix} \frac{WD1}{WD1} & \frac{WD1}{WD2} & \cdots\cdots & \frac{WD1}{WD2} \\ \frac{WD2}{WD1} & \frac{WD2}{WD2} & \cdots\cdots & \frac{WD2}{WDN} \\ \frac{WDN}{WD1} & \frac{WDN}{WD2} & \cdots\cdots & \frac{WDN}{WDN} \end{bmatrix} \tag{3.21}$$

Where, WD_i, which is just what we need, is unknown. $\frac{WD_i}{WD_j}$ which is the element of the judgment matrix *A* - *LD*, represent the relative importance of the *i*th load compared with the *j*th load. The value of *w* $\frac{D_i}{WD_j}$ can be obtained according to the experience of electrical engineers or system operator's using some ratio scale methods.

Similarly the judgment matrix *A* - *PI* can be written as follows:

$$\boldsymbol{A\text{-}PL} = \begin{bmatrix} \frac{WK1}{WK1} & \cdots\cdots & \frac{WK1}{WKN} \\ \frac{WK2}{WK1} & \cdots\cdots & \frac{WK2}{WKN} \\ \frac{WKN}{WK1} & \cdots\cdots & \frac{WKN}{WKN} \end{bmatrix} \tag{3.22}$$

Where *WK* *i* is un known. $\frac{WKi}{WKj}$, which is the element of judgment matrix *A-PI*, represents the relative importance of the *i*th load center compared with the jth load center. The value of WK_i/WK_j can also be obtained according to the experience of electrical engineers or system operators using some ratio scale methods.

Therefore, the unified weighting factor of the load w I can be obtained from the following equation:

$$W_i = WK_j \times WD_i \times D_i \in K_j \qquad (3.23)$$

Where $D_i \in K_j$ means load D_i is located in load center K_j [3].

3.4 Applying AHP Method at Sudanese Network

Sudanese network comprised 82 bus (53) of it is load buses these buses have different values and important, according to AHP method the total load will be divided into three load centers (CK1, CK2, CK3), CK1 will include 14 load buses, CK2 will include 17 load buses and CK3 will include 22 load buses, by using AHP two judgment matrixes will be founded.

When this matrix weighting factors implemented many factors should be considered:

1. The experience of Sudanese working engineers and designer.
2. Political areas.
3. Military areas.
4. Economical areas.
5. Industrial areas.
6. Agricultural areas.
7. Residential areas.

For example industrial areas Alkhortoum Bahry, Atbra and Rbk. Agricultural areas Algazeera, Algadref, Alshmaleeyah and Senar.

Economical areas Portsudan, Alkhortoum and Oumdurman. Political areas Darfor.

The factors will be shown at table (3.1), table (3.2), table (3.3) and Table (3.4) as follow:

Table (3.1): Weighting Factors of Load Center Buses (CK1)

BUS	**WEIGHT**	**CK1**
12	3	ATB2
9	3	DON2
61	3	SHG1
10	4	MWT2
46	4	KSL2
44	4	NHLF2
60	4	LOM1
13	5	SHN2
80	5	FAO1
23	6	GAD2
39	6	FUL2
43	6	SHK2
58	6	AFR1
73	6	MAR1B1

Table (3.2): Weighting Factors of Load Center Buses (CK2)

BUS	WEIGHT	CK2
81	6	GDF1
34	6	HAG
26	7	MAR2
77	7	HAG1
54	7	KUK
63	7	BNT1
62	7	MUG
52	8	IBA1
20	8	MHD2
30	8	SNG2
29	8	SNJ2
64	8	OMD
28	8	RBK2
2	9	ATB5
59	9	KLX1
14	9	MRk2
3	9	MRK5

Table (3.3): Weighting Factors of Load Center Buses (CK3)

BUS	WEIGHT	CK3
70	1	NHAS1
34	1	OBD2

50	1	KHE1
51	1	IZB1
55	1	IZG1
57	1	FAR1
71	2	HAS1
32	2	RNK2
33	2	HWT2
35	2	UMR2
67	2	BAG1
79	2	MIN1
72	2	GND1
74	2	MAN1
5	2	WHL2
22	3	DEB2
17	3	FRZ2
27	3	MSH2
36	3	TND2
75	3	ORBR1
38	3	ZBD2
40	3	BBN2

Table (3.4): Individual Weighting Factors of Load Center Buses (CK)

CK1	CK2	CK3
6	9	3

And from it we will have the following judgment matrix factor

Y_1=

9/9	9/8	9/8	9/8	9/7	9/8	9/7	9/9	9/6	9/7	9/7	9/6	9/7	9/8	9/8	9/9	9/9	9/3	9/6	9/5	9/4	9/6	9/4	9/4	9/6	9/3	9/3
8/9	8/8	8/8	8/8	8/7	8/8	8/7	8/9	8/6	8/7	8/7	8/6	8/7	8/8	8/8	8/9	8/9	8/3	8/6	8/5	8/4	8/6	8/4	8/4	8/6	8/3	8/3
8/9	8/8	8/8	8/8	8/7	8/8	8/7	8/9	8/6	8/7	8/7	8/6	8/7	8/8	8/8	8/9	8/9	8/3	8/6	8/5	8/4	8/6	8/4	8/4	8/6	8/3	8/3
8/9	8/8	8/8	8/8	8/7	8/8	8/7	8/9	8/6	8/7	8/7	8/6	8/7	8/8	8/8	8/9	8/9	8/3	8/6	8/5	8/4	8/6	8/4	8/4	8/6	8/3	8/3
7/9	7/8	7/8	7/8	7/7	7/8	7/7	7/9	7/6	7/7	7/7	7/6	7/7	7/8	7/8	7/9	7/9	7/3	7/6	7/5	7/4	7/6	7/4	7/4	7/6	7/3	7/3
8/9	8/8	8/8	8/8	8/7	8/8	8/7	8/9	8/6	8/7	8/7	8/6	8/7	8/8	8/8	8/9	8/9	8/3	8/6	8/5	8/4	8/6	8/4	8/4	8/6	8/3	8/3
7/9	7/8	7/8	7/8	7/7	7/8	7/7	7/9	7/6	7/7	7/7	7/6	7/7	7/8	7/8	7/9	7/9	7/3	7/6	7/5	7/4	7/6	7/4	7/4	7/6	7/3	7/3
9/9	9/8	9/8	9/8	9/7	9/8	9/7	9/9	9/6	9/7	9/7	9/6	9/7	9/8	9/8	9/9	9/9	9/3	9/6	9/5	9/4	9/6	9/4	9/4	9/6	9/3	9/3
6/9	6/8	6/8	6/8	6/7	6/8	6/7	6/9	6/6	6/7	6/7	6/6	6/7	6/8	6/8	6/9	6/9	6/3	6/6	6/5	6/4	6/6	6/4	6/4	4/6	6/3	6/3
7/9	7/8	7/8	7/8	7/7	7/8	7/7	7/9	7/6	7/7	7/7	7/6	7/7	7/8	7/8	7/9	7/9	7/3	7/6	7/5	7/4	7/6	7/4	7/4	7/6	7/3	7/3
7/9	7/8	7/8	7/8	7/7	7/8	7/7	7/9	7/6	7/7	7/7	7/6	7/7	7/8	7/8	7/9	7/9	7/3	7/6	7/5	7/4	7/6	7/4	7/4	7/6	7/3	7/3
6/9	6/8	6/8	6/8	6/7	6/8	6/7	6/9	6/6	6/7	6/7	6/6	6/7	6/8	6/8	6/9	6/9	6/3	6/6	6/5	6/4	6/6	6/4	6/4	4/6	6/3	6/3
7/9	7/8	7/8	7/8	7/7	7/8	7/7	7/9	7/6	7/7	7/7	7/6	7/7	7/8	7/8	7/9	7/9	7/3	7/6	7/5	7/4	7/6	7/4	7/4	7/6	7/3	7/3
8/9	8/8	8/8	8/8	8/7	8/8	8/7	8/9	8/6	8/7	8/7	8/6	8/7	8/8	8/8	8/9	8/9	8/3	8/6	8/5	8/4	8/6	8/4	8/4	8/6	8/3	8/3
8/9	8/8	8/8	8/8	8/7	8/8	8/7	8/9	8/6	8/7	8/7	8/6	8/7	8/8	8/8	8/9	8/9	8/3	8/6	8/5	8/4	8/6	8/4	8/4	8/6	8/3	8/3
9/9	9/8	9/8	9/8	9/7	9/8	9/7	9/9	9/6	9/7	9/7	9/6	9/7	9/8	9/8	9/9	9/9	9/3	9/6	9/5	9/4	9/6	9/4	9/4	9/6	9/3	9/3
9/9	9/8	9/8	9/8	9/7	9/8	9/7	9/9	9/6	9/7	9/7	9/6	9/7	9/8	9/8	9/9	9/9	9/3	9/6	9/5	9/4	9/6	9/4	9/4	9/6	9/3	9/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3	3/3
6/9	6/8	6/8	6/8	6/7	6/8	6/7	6/9	6/6	6/7	6/7	6/6	6/7	6/8	6/8	6/9	6/9	6/3	6/6	6/5	6/4	6/6	6/4	6/4	4/6	6/3	6/3
5/9	5/8	5/8	5/8	5/7	5/8	5/7	5/9	5/6	5/7	5/7	5/6	5/7	5/8	5/8	5/9	5/9	5/3	5/6	5/5	5/4	5/6	5/4	5/4	5/6	5/3	5/3
4/9	4/8	4/8	4/8	4/7	4/8	4/7	4/9	4/6	4/7	4/7	4/6	4/7	4/8	4/8	4/9	4/9	4/3	4/6	4/5	4/4	4/6	4/4	4/4	4/6	4/3	4/3
6/9	6/8	6/8	6/8	6/7	6/8	6/7	6/9	6/6	6/7	6/7	6/6	6/7	6/8	6/8	6/9	6/9	6/3	6/6	6/5	6/4	6/6	6/4	6/4	4/6	6/3	6/3
4/9	4/8	4/8	4/8	4/7	4/8	4/7	4/9	4/6	4/7	4/7	4/6	4/7	4/8	4/8	4/9	4/9	4/3	4/6	4/5	4/4	4/6	4/4	4/4	4/6	4/3	4/3
4/9	4/8	4/8	4/8	4/7	4/8	4/7	4/9	4/6	4/7	4/7	4/6	4/7	4/8	4/8	4/9	4/9	4/3	4/6	4/5	4/4	4/6	4/4	4/4	4/6	4/3	4/3
6/9	6/8	6/8	6/8	6/7	6/8	6/7	6/9	6/6	6/7	6/7	6/6	6/7	6/8	6/8	6/9	6/9	6/3	6/6	6/5	6/4	6/6	6/4	6/4	4/6	6/3	6/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3	3/3
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4/9	4/8	4/8	4/8	4/7	4/8	4/7	4/9	4/6	4/7	4/7	4/6	4/7	4/8	4/8	4/9	4/9	4/3	4/6	4/5	4/4	4/6	4/4	4/4	4/6	4/3	4/3
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6/9	6/8	6/8	6/8	6/7	6/8	6/7	6/9	6/6	6/7	6/7	6/6	6/7	6/8	6/8	6/9	6/9	6/3	6/6	6/5	6/4	6/6	6/4	6/4	4/6	6/3	6/3

Y_2=

9/4	9/6	9/6	9/5	9/3	9/2	9	9/3	9/3	9/2	9	9/2	9/2	9/3	9	9	9	9	9/2	9/2	9/2	9/3	9/2	9/3	9/3	9/2
8/4	8/6	8/6	8/5	8/3	8/2	8	8/3	8/3	8/2	8	8/2	8/2	8/3	8	8	8	8	8/2	8/2	8/2	8/3	8/2	8/3	8/3	8/2
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8/4	8/6	8/6	8/5	8/3	8/2	8	8/3	8/3	8/2	8	8/2	8/2	8/3	8	8	8	8	8/2	8/2	8/2	8/3	8/2	8/3	8/3	8/2
7/4	7/6	7/6	7/5	7/3	7/2	7	7/3	7/3	7/2	7	7/2	7/2	7/3	7	7	7	7	7/2	7/2	7/2	7/3	7/2	7/3	7/3	7/2
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6/4	6/6	6/6	6/5	6/3	6/2	6	6/3	6/3	6/2	6	6/2	6/2	6/3	6	6	6	6	6/2	6/2	6/2	6/3	6/2	6/3	6/3	6/2
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7/4	7/6	7/6	7/5	7/3	7/2	7	7/3	7/3	7/2	7	7/2	7/2	7/3	7	7	7	7	7/2	7/2	7/2	7/3	7/2	7/3	7/3	7/2
8/4	8/6	8/6	8/5	8/3	8/2	8	8/3	8/3	8/2	8	8/2	8/2	8/3	8	8	8	8	8/2	8/2	8/2	8/3	8/2	8/3	8/3	8/2
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5/4	5/6	5/6	5/5	5/3	5/2	5	5/3	5/3	5/2	5	5/2	5/2	5/3	5	5	5	5	5/2	5/2	5/2	5/3	5/2	5/3	5/3	5/2
4/4	4/6	4/6	4/5	4/3	4/2	4	4/3	4/3	4/2	4	4/2	4/2	4/3	4	4	4	4	4/2	4/2	4/2	4/3	4/2	4/3	4/3	4/2
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4/4	4/6	4/6	4/5	4/3	4/2	4	4/3	4/3	4/2	4	4/2	4/2	4/3	4	4	4	4	4/2	4/2	4/2	4/3	4/2	4/3	4/3	4/2
4/4	4/6	4/6	4/5	4/3	4/2	4	4/3	4/3	4/2	4	4/2	4/2	4/3	4	4	4	4	4/2	4/2	4/2	4/3	4/2	4/3	4/3	4/2
6/4	6/6	6/6	6/5	6/3	6/2	6	6/3	6/3	6/2	6	6/2	6/2	6/3	6	6	6	6	6/2	6/2	6/2	6/3	6/2	6/3	6/3	6/2
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3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
4/4	4/6	4/6	4/5	4/3	4/2	4	4/3	4/3	4/2	4	4/2	4/2	4/3	4	4	4	4	4/2	4/2	4/2	4/3	4/2	4/3	4/3	4/2
6/4	6/6	6/6	6/5	6/3	6/2	6	6/3	6/3	6/2	6	6/2	6/2	6/3	6	6	6	6	6/2	6/2	6/2	6/3	6/2	6/3	6/3	6/2
6/4	6/6	6/6	6/5	6/3	6/2	6	6/3	6/3	6/2	6	6/2	6/2	6/3	6	6	6	6	6/2	6/2	6/2	6/3	6/2	6/3	6/3	6/2
5/4	5/6	5/6	5/5	5/3	5/2	5	5/3	5/3	5/2	5	5/2	5/2	5/3	5	5	5	5	5/2	5/2	5/2	5/3	5/2	5/3	5/3	5/2
3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2

Y_3=

3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3
4/9	4/8	4/8	4/8	4/7	4/8	4/7	4/9	4/6	4/7	4/7	4/6	4/7	4/8	4/8	4/9	4/9	4/3	4/6	4/5	4/4	4/6	4/4	4/4	4/6	4/3
6/9	6/8	6/8	6/8	6/7	6/8	6/7	6/9	6/6	6/7	6/7	6/6	6/7	6/8	6/8	6/9	6/9	6/3	6/6	6/5	6/4	6/6	6/4	6/4	4/6	6/3
6/9	6/8	6/8	6/8	6/7	6/8	6/7	6/9	6/6	6/7	6/7	6/6	6/7	6/8	6/8	6/9	6/9	6/3	6/6	6/5	6/4	6/6	6/4	6/4	4/6	6/3
5/9	5/8	5/8	5/8	5/7	5/8	5/7	5/9	5/6	5/7	5/7	5/6	5/7	5/8	5/8	5/9	5/9	5/3	5/6	5/5	5/4	5/6	5/4	5/4	5/6	5/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3
1/9	1/8	1/8	1/8	1/7	1/8	1/7	1/9	1/6	1/7	1/7	1/6	1/7	1/8	1/8	1/9	1/9	1/3	1/6	1/5	1/4	1/6	1/4	1/4	1/6	1/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3
1/9	1/8	1/8	1/8	1/7	1/8	1/7	1/9	1/6	1/7	1/7	1/6	1/7	1/8	1/8	1/9	1/9	1/3	1/6	1/5	1/4	1/6	1/4	1/4	1/6	1/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3
1/9	1/8	1/8	1/8	1/7	1/8	1/7	1/9	1/6	1/7	1/7	1/6	1/7	1/8	1/8	1/9	1/9	1/3	1/6	1/5	1/4	1/6	1/4	1/4	1/6	1/3
1/9	1/8	1/8	1/8	1/7	1/8	1/7	1/9	1/6	1/7	1/7	1/6	1/7	1/8	1/8	1/9	1/9	1/3	1/6	1/5	1/4	1/6	1/4	1/4	1/6	1/3
1/9	1/8	1/8	1/8	1/7	1/8	1/7	1/9	1/6	1/7	1/7	1/6	1/7	1/8	1/8	1/9	1/9	1/3	1/6	1/5	1/4	1/6	1/4	1/4	1/6	1/3
1/9	1/8	1/8	1/8	1/7	1/8	1/7	1/9	1/6	1/7	1/7	1/6	1/7	1/8	1/8	1/9	1/9	1/3	1/6	1/5	1/4	1/6	1/4	1/4	1/6	1/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3
3/9	3/8	3/8	3/8	3/7	3/8	3/7	3/9	3/6	3/7	3/7	3/6	3/7	3/8	3/8	3/9	3/9	3/3	3/6	3/5	3/4	3/6	3/4	3/4	3/6	3/3
2/9	2/8	2/8	2/8	2/7	2/8	2/7	2/9	2/6	2/7	2/7	2/6	2/7	2/8	2/8	2/9	2/9	2/3	2/6	2/5	2/4	2/6	2/4	2/4	2/6	2/3

Y_4=

5/3	5/3	5/4	5/6	5/6	5/5	5/3	5/2	5	5/3	5/3	5/2	5	5/2	5/2	5/3	5	5	5	5	5/2	5/2	5/2	5/3	5/2	5/3	5/3	5/2
3/3	3/3	3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2
1/3	1/3	1/4	1/6	1/6	1/5	1/3	1/2	1	1/3	1/3	1/2	1	1/2	1/2	1/3	1	1	1	1	1/2	1/2	1/2	1/3	1/2	1/3	1/3	1/2
3/3	3/3	3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
3/3	3/3	3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2
1/3	1/3	1/4	1/6	1/6	1/5	1/3	1/2	1	1/3	1/3	1/2	1	1/2	1/2	1/3	1	1	1	1	1/2	1/2	1/2	1/3	1/2	1/3	1/3	1/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2
3/3	3/3	3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
1/3	1/3	1/4	1/6	1/6	1/5	1/3	1/2	1	1/3	1/3	1/2	1	1/2	1/2	1/3	1	1	1	1	1/2	1/2	1/2	1/3	1/2	1/3	1/3	1/2
1/3	1/3	1/4	1/6	1/6	1/5	1/3	1/2	1	1/3	1/3	1/2	1	1/2	1/2	1/3	1	1	1	1	1/2	1/2	1/2	1/3	1/2	1/3	1/3	1/2
1/3	1/3	1/4	1/6	1/6	1/5	1/3	1/2	1	1/3	1/3	1/2	1	1/2	1/2	1/3	1	1	1	1	1/2	1/2	1/2	1/3	1/2	1/3	1/3	1/2
1/3	1/3	1/4	1/6	1/6	1/5	1/3	1/2	1	1/3	1/3	1/2	1	1/2	1/2	1/3	1	1	1	1	1/2	1/2	1/2	1/3	1/2	1/3	1/3	1/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2
3/3	3/3	3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2
3/3	3/3	3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
3/3	3/3	3/4	3/6	3/6	3/5	3/3	3/2	3	3/3	3/3	3/2	3	3/2	3/2	3/3	3	3	3	3	3/2	3/2	3/2	3/3	3/2	3/3	3/3	3/2
2/3	2/3	2/4	2/6	2/6	2/5	2/3	2/2	2	2/3	2/3	2/2	2	2/2	2/2	2/3	2	2	2	2	2/2	2/2	2/2	2/3	2/2	2/3	2/3	2/2]

Then A-LD matrix:

$$\begin{bmatrix} Y1 & Y2 \\ Y3 & Y4 \end{bmatrix} \tag{3.24}$$

The A-PL matrix:

$$\begin{bmatrix} 9/9 & 9/6 & 9/3 \\ 6/9 & 6/6 & 6/3 \\ 3/9 & 3/6 & 3/3 \end{bmatrix} \tag{3.25}$$

By applying equations (3.4) ,(3.5) ,(3.6) to find the vector matrix (W_i) form A-PL(Wk)and A-LD (WD), while(i)is varying from (0-53),the table (3.4) will show every load at Sudanese with it proper weighting factor.

Table 3.5: Sudan network load ranked according to AHP weighting factors

Bus name	Bus No	Load	Weight
MUG	62	75.466	0.0007
NHAS1	70	24.73	0.0007
OHAS1	71	11.088	0.0007
GND1	72	27.821	0.0007
MAR1B1	73	56.717	0.0007
AFR1	58	17.203	0.0014
SHG1	61	64.915	0.0014
BNT1	63	59.069	0.0014
OMD1	64	81.312	0.0014
MAN1	74	10.886	0.0014
ORBK1	75	0.336	0.0014
HAG1	77	7.594	0.0014
MIN1	79	14.381	0.0014
GRB6	82	15.254	0.0014
BAG1	67	36.49	0.0021
SNP1	78	4.704	0.0021
FAO1	80	11.021	0.0021
GDF1	81	18.614	0.0021
FAR1	57	50.266	0.0028
KSL2	46	16.666	0.0042
KHE1	50	81.917	0.0042
MHD1	56	12.634	0.0042
KLX1	59	40.387	0.0042

LOM1	60	85.344	0.0042
BBN2	40	3.36	0.0055
SHK2	43	0.672	0.0055
IZB1	51	68.006	0.0055
UMR2	35	3.629	0.0062
IZG1	55	74.189	0.0069
NHLF2	44	12.029	0.0082
IBA1	52	41.328	0.0082
KUK1	54	44.621	0.0082
ZBD2	38	3.36	0.0083
DBT2	37	6.25	0.0104
GAD2	23	14.112	0.0124
SNJ2	29	16.464	0.0124
TND2	36	1.008	0.0124
FUL2	39	6.72	0.0124
ATB2	12	101.338	0.0145
FRZ2	17	13.574	0.0145
MSH2	27	6.989	0.0145
RBK2	28	46.704	0.0145
SNG2	30	12.029	0.0145

AHP method give the totally view of The load ranking using weighting factors from judgment matrix (3.24) , (3.25) and the priority of the load and it important according to the other load as shown in table(3.1), table(3.2) table(3.3) and table(3.4). And it will be easily to manage load shedding using proper programs and equipment which will already been installed at the electrical network. From this point a software program will be included at chapter 4 that will employ all weighting factors for proper load shedding using ETAP.

CHAPTER FOUR

SIMULATION AND RESULTS

4.1 Introduction

Figure (appendix (A)) show single line diagram for Sudanese power grid with voltages level 500 KV, 220 KV, 110 KV.

The Sudanese power grid has the following characteristic:

Table 4.1: Sudanese power grid characteristic

Number of Buses	82
Number of Lines	81
Power Plants	8
Loads	53
Shunts	10
Transformers	15

The problem causes by loss of part of generation (one power plant or machines get out of synchronization), This problem causes instability for power system (black out), that must be clear this disturbance very fast in small time.

To solve like this problem must be used the intelligent load shedding that to shed some loads to improve system stability this function was found in ETAP Program when it connected on line with network.

First the priority of loads has been calculated by means AHP method as shown at chapter three, and had been inserted at ETAP.

The result of this method as follow:

Table 4.2 priority of the Sudanese grid loads

Bus name	Bus No	Load	Weight
MUG	62	75.466	0.0007
NHAS1	70	24.73	0.0007
OHAS1	71	11.088	0.0007
GND1	72	27.821	0.0007
MAR1B1	73	56.717	0.0007
AFR1	58	17.203	0.0014
SHG1	61	64.915	0.0014
BNT1	63	59.069	0.0014
OMD1	64	81.312	0.0014
MAN1	74	10.886	0.0014
ORBK1	75	0.336	0.0014
HAG1	77	7.594	0.0014
MIN1	79	14.381	0.0014
GRB6	82	15.254	0.0014
BAG1	67	36.49	0.0021
SNP1	78	4.704	0.0021
FAO1	80	11.021	0.0021
GDF1	81	18.614	0.0021
FAR1	57	50.266	0.0028
KSL2	46	16.666	0.0042
KHE1	50	81.917	0.0042

MHD1	56	12.634	0.0042
KLX1	59	40.387	0.0042
LOM1	60	85.344	0.0042
BBN2	40	3.36	0.0055
SHK2	43	0.672	0.0055
IZB1	51	68.006	0.0055
UMR2	35	3.629	0.0062
IZG1	55	74.189	0.0069
NHLF2	44	12.029	0.0082
IBA1	52	41.328	0.0082
KUK1	54	44.621	0.0082
ZBD2	38	3.36	0.0083
DBT2	37	6.25	0.0104
GAD2	23	14.112	0.0124
SNJ2	29	16.464	0.0124
TND2	36	1.008	0.0124
FUL2	39	6.72	0.0124
ATB2	12	101.338	0.0145
FRZ2	17	13.574	0.0145
MSH2	27	6.989	0.0145
RBK2	28	46.704	0.0145
SNG2	30	12.029	0.0145
DEB2-B2	7	33.456	0.0166
DON2	9	50.32	0.0166
MWT2	10	29.808	0.0166

SHN2	13	33.264	0.0166
ROS2	31	8.333	0.0166
RNK2	32	0.403	0.0166
WHL2	5	14.36	0.0187
MHD2	20	60.883	0.0187
HWT2	33	1.546	0.0187
OBD2	34	19.757	0.0187

4.2 Sudanese Grid (Case Study)

Sudanese power grid had been studied under three cases that shown load flow, buses voltages and overall performance of Sudanese network at $\pm 5\%$ of the nominal voltage as acceptable statutory voltage limits.

These cases are: normal condition, loss of generation and after shedding condition, above cases in details:

4.2.1 Normal Condition

At normal condition all plants generated power for the grid and bus voltages quite stable, all voltages of all bus bars will be considered as references for the other cases.

After implementing Sudanese network at ETAP program the following bus bars voltages and conditions is being shown at table (4.3) below:

Table 4.3: bus voltages under normal condition

Bus ID	Nominal kV	Type	Normal case Voltage
Bus 01	500	SWNG	100
Bus 02	500	Load	100.24
Bus 03	500	Load	99.01
Bus 04	500	Load	99.52
Bus 05	220	Load	98.78
Bus 06	220	Load	101.91
Bus 07	220	Load	102.04
Bus 08	220	Load	104.31
Bus 09	220	Load	102.43
Bus 10	220	Load	103.05
Bus 11	220	Load	103.75
Bus12	220	Load	92.75
Bus 13	220	Load	97.07
Bus 14	220	Load	99.91
Bus 15	220	Load	98.47
Bus 16	220	Load	99.09
Bus 17	220	Load	99.82
Bus 18	220	Gen.	100
Bus 19	220	Load	99.59
Bus 20	220	Load	99.43
Bus 21	220	Load	99.39
Bus 22	220	Load	98.34

Bus 23	220	Load	98.55
Bus 24	220	Load	99.21
Bus 25	220	Load	96.54
Bus 26	220	Load	96.76
Bus 27	220	Load	99.82
Bus 28	220	Gen.	100
Bus 29	220	Load	98.59
Bus 30	220	Load	100.1
Bus 31	220	Gen.	100
Bus 32	220	Load	100.79
Bus 33	220	Load	100.98
Bus 34	220	Load	99.89
Bus 35	220	Load	100.55
Bus 36	220	Load	100.72
Bus 37	220	Load	100.21
Bus 38	220	Load	100.08
Bus 39	220	Load	100.26
Bus 40	220	Load	100.46
Bus 41	220	Load	100.95
Bus 42	220	Load	100.71
Bus 43	220	Load	100.96
Bus 44	220	Load	100.69
Bus 45	220	Load	101.4
Bus 46	220	Load	101.29
Bus 47	220	Load	99.57

Bus 48	220	Load	101
Bus 49	220	Gen.	100
Bus 50	110	Load	98.34
Bus 51	110	Load	96.76
Bus 52	110	Load	97.48
Bus 53	110	Gen.	100
Bus 54	110	Load	98.61
Bus 55	110	Load	98.14
Bus 56	110	Load	97.48
Bus 57	110	Load	93.55
Bus 58	110	Load	94.3
Bus 59	110	Load	95.05
Bus 60	110	Load	95.02
Bus 61	110	Load	95.67
Bus 62	110	Load	95.98
Bus 63	110	Load	96.36
Bus 64	110	Load	96.48
Bus 65	110	Load	98.49
Bus 66	110	Load	100.24
Bus 67	110	Load	92.71
Bus 68	110	Load	94.21
Bus 69	110	Load	93.07
Bus 70	110	Load	103.72
Bus 71	110	Load	103.4
Bus 72	110	Load	103.07

Bus 73	110	Load	102.46
Bus 74	110	Load	101.4
Bus 75	110	Load	101.24
Bus 76	110	Load	101.28
Bus 77	110	Load	100.87
Bus 78	110	Gen.	100
Bus 79	110	Load	94.82
Bus 80	110	Load	100.43
Bus 81	110	Load	102.41
Bus 82	66	Gen.	100

4.2.2 Loss of Generation Condition

At this case the power grid loss the generation in GERRY power plant that causes instability in bus bars voltages. After implementing Sudanese network at ETAP program the following bus bars voltages loss of GERRY plant condition is being shown at table (4.4) below.

At this case the bus voltages decreased from nominal value to other value, some buses have less change for example from bus2 to bus4 also from bus12 to bus15,also some buses have large effect due to loss of generation in GERRY power plant for example from bus16 to bus18 these voltages decreased from nominal limit to marginal limit.

Table 4.4: Sudanese grid bus voltages at loss of generation condition

Bus ID	Nominal KV	Type	Normal case Voltage	Loss of gen Voltage
Bus 01	500	SWNG	100	100
Bus 02	500	Load	100.24	99.11
Bus 03	500	Load	99.01	97.29
Bus 04	500	Load	99.52	97.59
Bus 05	220	Load	98.78	98.78
Bus 06	220	Load	101.91	101.91
Bus 07	220	Load	102.04	102.04
Bus 08	220	Load	104.31	104.31
Bus 09	220	Load	102.43	102.43
Bus 10	220	Load	103.05	103.05
Bus 11	220	Load	103.75	103.75
Bus12	220	Load	92.75	90.76
Bus 13	220	Load	97.07	93.84
Bus 14	220	Load	99.91	98.49
Bus 15	220	Load	98.47	97.11
Bus 16	220	Load	99.09	96
Bus 17	220	Load	99.82	96
Bus 18	220	Gen.	100	96.07

Bus 19	220	Load	99.59	96.86
Bus 20	220	Load	99.43	98.03
Bus 21	220	Load	99.39	96.95
Bus 22	220	Load	98.34	97.02
Bus 23	220	Load	98.55	96.91
Bus 24	220	Load	99.21	96.95
Bus 25	220	Load	96.54	95.34
Bus 26	220	Load	96.76	95.84
Bus 27	220	Load	99.82	99.82
Bus 28	220	Gen.	100	100
Bus 29	220	Load	98.59	98.06
Bus 30	220	Load	100.1	99.74
Bus 31	220	Gen.	100	100
Bus 32	220	Load	100.79	100.79
Bus 33	220	Load	100.98	100.71
Bus 34	220	Load	99.89	99.89
Bus 35	220	Load	100.55	100.55
Bus 36	220	Load	100.72	100.72
Bus 37	220	Load	100.21	100.21
Bus 38	220	Load	100.08	100.08
Bus 39	220	Load	100.26	100.26

Bus 40	220	Load	100.46	100.46
Bus 41	220	Load	100.95	100.78
Bus 42	220	Load	100.71	100.55
Bus 43	220	Load	100.96	100.79
Bus 44	220	Load	100.69	100.53
Bus 45	220	Load	101.4	101.24
Bus 46	220	Load	101.29	101.13
Bus 47	220	Load	99.57	98.16
Bus 48	220	Load	101	100.83
Bus 49	220	Gen.	100	100
Bus 50	110	Load	98.34	98.17
Bus 51	110	Load	96.76	96.24
Bus 52	110	Load	97.48	96.96
Bus 53	110	Gen.	100	100
Bus 54	110	Load	98.61	98.43
Bus 55	110	Load	98.14	97.83
Bus 56	110	Load	97.48	96.96
Bus 57	110	Load	93.55	92.64
Bus 58	110	Load	94.3	93.41
Bus 59	110	Load	95.05	94.16
Bus 60	110	Load	95.02	94.14

Bus 61	110	Load	95.67	94.79
Bus 62	110	Load	95.98	95.19
Bus 63	110	Load	96.36	95.59
Bus 64	110	Load	96.48	95.81
Bus 65	110	Load	98.49	97.61
Bus 66	110	Load	100.24	99.19
Bus 67	110	Load	92.71	91.5
Bus 68	110	Load	94.21	93.2
Bus 69	110	Load	93.07	91.83
Bus 70	110	Load	103.72	102.43
Bus 71	110	Load	103.4	102.11
Bus 72	110	Load	103.07	101.78
Bus 73	110	Load	102.46	101.52
Bus 74	110	Load	101.4	100.46
Bus 75	110	Load	101.24	101.14
Bus 76	110	Load	101.28	101.19
Bus 77	110	Load	100.87	100.28
Bus 78	110	Gen.	100	100
Bus 79	110	Load	94.82	94.82
Bus 80	110	Load	100.43	99.7
Bus 81	110	Load	102.41	102.15

Bus 82	66	Gen.	100	100

4.2.3 Load Shedding Condition

This case represents the solution to clear this disturbance the ETAP program do this function that it will shed the load has less priority one by one and check the network (by employed the load flow) it will stop to shed after the generation been equal or less minimum than generation, at this case the ETAP shed the MUG, NHAS1, OHAS1, and GND1 one after one after this shedding generally the system stability improved and voltages of buses increased for example bus16,bus17and bus81 the voltage raise to value near to nominal limit.

Table 4.5: Sudanese grid bus voltages at load shedding condition

Bus ID	Nominal kV	Type	Normal case Voltage	Loss of gen Voltage	Load shedding Voltage
Bus 01	500	SWNG	100	100	100
Bus 02	500	Load	100.24	99.11	99.66
Bus 03	500	Load	99.01	97.29	98.57
Bus 04	500	Load	99.52	97.59	98.95
Bus 05	220	Load	98.78	98.78	98.78
Bus 06	220	Load	101.91	101.91	101.91
Bus 07	220	Load	102.04	102.04	102.04
Bus 08	220	Load	104.31	104.31	104.31

Bus 09	220	Load	102.43	102.43	102.43
Bus 10	220	Load	103.05	103.05	103.05
Bus 11	220	Load	103.75	103.75	103.75
Bus12	220	Load	92.75	90.76	91.63
Bus 13	220	Load	97.07	93.84	95.18
Bus 14	220	Load	99.91	98.49	99.98
Bus 15	220	Load	98.47	97.11	98.58
Bus 16	220	Load	99.09	96	97.47
Bus 17	220	Load	99.82	96	97.48
Bus 18	220	Gen.	100	96.07	97.55
Bus 19	220	Load	99.59	96.86	98.36
Bus 20	220	Load	99.43	98.03	99.53
Bus 21	220	Load	99.39	96.95	98.49
Bus 22	220	Load	98.34	97.02	98.41
Bus 23	220	Load	98.55	96.91	98.54
Bus 24	220	Load	99.21	96.95	98.51
Bus 25	220	Load	96.54	95.34	97.77
Bus 26	220	Load	96.76	95.84	97.77
Bus 27	220	Load	99.82	99.82	99.82
Bus 28	220	Gen.	100	100	100
Bus 29	220	Load	98.59	98.06	99.18

Bus 30	220	Load	100.1	99.74	100.5
Bus 31	220	Gen.	100	100	100
Bus 32	220	Load	100.79	100.79	100.79
Bus 33	220	Load	100.98	100.71	101.29
Bus 34	220	Load	99.89	99.89	99.89
Bus 35	220	Load	100.55	100.55	100.55
Bus 36	220	Load	100.72	100.72	100.72
Bus 37	220	Load	100.21	100.21	100.21
Bus 38	220	Load	100.08	100.08	100.08
Bus 39	220	Load	100.26	100.26	100.26
Bus 40	220	Load	100.46	100.46	100.46
Bus 41	220	Load	100.95	100.78	101.15
Bus 42	220	Load	100.71	100.55	100.89
Bus 43	220	Load	100.96	100.79	101.15
Bus 44	220	Load	100.69	100.53	100.87
Bus 45	220	Load	101.4	101.24	101.58
Bus 46	220	Load	101.29	101.13	101.47
Bus 47	220	Load	99.57	98.16	99.65
Bus 48	220	Load	101	100.83	101.19
Bus 49	220	Gen.	100	100	100
Bus 50	110	Load	98.34	98.17	98.37

Bus 51	110	Load	96.76	96.24	96.49
Bus 52	110	Load	97.48	96.96	97.21
Bus 53	110	Gen.	100	100	100
Bus 54	110	Load	98.61	98.43	98.64
Bus 55	110	Load	98.14	97.83	98.39
Bus 56	110	Load	97.48	96.96	97.9
Bus 57	110	Load	93.55	92.64	93.71
Bus 58	110	Load	94.3	93.41	94.47
Bus 59	110	Load	95.05	94.16	95.21
Bus 60	110	Load	95.02	94.14	95.29
Bus 61	110	Load	95.67	94.79	96.19
Bus 62	110	Load	95.98	95.19	96.92
Bus 63	110	Load	96.36	95.59	97.17
Bus 64	110	Load	96.48	95.81	97.15
Bus 65	110	Load	98.49	97.61	99.16
Bus 66	110	Load	100.24	99.19	100.59
Bus 67	110	Load	92.71	91.5	92.99
Bus 68	110	Load	94.21	93.2	94.41
Bus 69	110	Load	93.07	91.83	93.37
Bus 70	110	Load	103.72	102.43	106.61
Bus 71	110	Load	103.4	102.11	106.4

Bus 72	110	Load	103.07	101.78	106.41
Bus 73	110	Load	102.46	101.52	103.59
Bus 74	110	Load	101.4	100.46	102.55
Bus 75	110	Load	101.24	101.14	101.32
Bus 76	110	Load	101.28	101.19	101.36
Bus 77	110	Load	100.87	100.28	101.59
Bus 78	110	Gen.	100	100	100
Bus 79	110	Load	94.82	94.82	94.82
Bus 80	110	Load	100.43	99.7	101.31
Bus 81	110	Load	102.41	102.15	102.67
Bus 82	66	Gen.	100	100	100

4.3 Buses Voltages Differences with References

This means the difference of voltage at normal case with case of loss of generation at GERRY power plant and case of load shedding. we noted that the difference in voltage increased at case of loss of generation at GERRY power plant for example bus13(-3.24%), bus14(-1.417%),bus16(-3.081%),bus51(-.523%),bus52(-.519%).at case of load shedding the difference decreased for example bus13(from -3.24% to1.896%), bus14(-1.417% to.068%), bus16(from -3.081% to -1.614%), bus51(from -.523% to-.271%), bus52(from -.519% to -.269%). most of this differences after shedding deceased from large marginal to less marginal.

Table 4.6: Buses Voltages Differences with References

Bus ID	Nominal kV	load flow	loss	load shedding
		Voltage	Voltage	Voltage
Bus 02	500	100.24	-1.13	-0.582
Bus 03	500	99.01	-1.722	-0.444
Bus 04	500	99.52	-1.931	-0.568
Bus12	220	92.75	-1.988	-1.117
Bus 13	220	97.07	-3.234	-1.896
Bus 14	220	99.91	-1.417	0.068
Bus 15	220	98.47	-1.358	0.114
Bus 16	220	99.09	-3.081	-1.614
Bus 17	220	99.82	-3.818	-2.342
Bus 18	220	100	-3.928	-2.449
Bus 19	220	99.59	-2.734	-1.238
Bus 20	220	99.43	-1.396	0.102
Bus 21	220	99.39	-2.446	-0.906
Bus 22	220	98.34	-1.325	0.069
Bus 23	220	98.55	-1.65	-0.018
Bus 24	220	99.21	-2.259	-0.695
Bus 25	220	96.54	-1.201	1.232
Bus 26	220	96.76	-0.923	1.012
Bus 29	220	98.59	-0.53	0.587
Bus 30	220	100.1	-0.362	0.406
Bus 32	220	100.79	0.001	-0.005
Bus 33	220	100.98	-0.274	0.307

Bus 41	220	100.95	-0.174	0.192
Bus 42	220	100.71	-0.16	0.177
Bus 43	220	100.96	-0.172	0.19
Bus 44	220	100.69	-0.16	0.177
Bus 45	220	101.4	-0.162	0.179
Bus 46	220	101.29	-0.162	0.179
Bus 47	220	99.57	-1.405	0.079
Bus 48	220	101	-0.172	0.191
Bus 50	110	98.34	-0.176	0.029
Bus 51	110	96.76	-0.523	-0.271
Bus 52	110	97.48	-0.519	-0.269
Bus 54	110	98.61	-0.176	0.029
Bus 55	110	98.14	-0.315	0.253
Bus 56	110	97.48	-0.523	0.421
Bus 57	110	93.55	-0.906	0.163
Bus 58	110	94.3	-0.898	0.162
Bus 59	110	95.05	-0.891	0.16
Bus 60	110	95.02	-0.887	0.263
Bus 61	110	95.67	-0.873	0.527
Bus 62	110	95.98	-0.793	0.941
Bus 63	110	96.36	-0.763	0.814
Bus 64	110	96.48	-0.672	0.664
Bus 65	110	98.49	-0.876	0.672
Bus 66	110	100.24	-1.057	0.351
Bus 67	110	92.71	-1.214	0.279

Bus 68	110	94.21	-1.007	0.199
Bus 69	110	93.07	-1.239	0.292
Bus 70	110	103.72	-1.288	2.887
Bus 71	110	103.4	-1.282	3.002
Bus 72	110	103.07	-1.287	3.346
Bus 73	110	102.46	-0.933	1.13
Bus 74	110	101.4	-0.947	1.146
Bus 75	110	101.24	-0.093	0.082
Bus 76	110	101.28	-0.092	0.081
Bus 77	110	100.87	-0.593	0.721
Bus 80	110	100.43	-0.737	0.878
Bus 81	110	102.41	-0.26	0.254

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The result of implementing the intelligent load shedding at Sudanese network system achieved the main purpose, that black out of the system can be avoided due to it:

1- Fast to shed the loads

2-Intelligent method to choice the proper loads

3- Automatic shedding which will implement the proper speed of shedding

4- Easy to avoid the network problems when became about loss of generation

5- Who ILS works as back up protection

6-Stability of the network due to current and voltage disturbance without intelligent load shedding the problem of overall Sudanese network black out will still happen more and more every year what shall Cost economical disaster, lost of generating machine, lost of power transformers, main transmissions lines, high maintenance cost and especially human lives.

5.2 Recommendations

Based on the results produced from these studies of ILS, the following was recommended:

1- ILS off time mode using ETAP will provide the status of the Sudanese network stability before and after clearing loads with no taking in considered the speed of operation which should be considered.

2- High recommended to implement the function of real time data that studying ILS depends basically on real time data from Sudanese network for the speed of operation will be considered.

3-Implementing real time data will require hardware tools that should simulate the data flowing with accuracy and suitable speed.

4- Economical study should be considered for implementing the ILS system.

5- A coordination study between distribution and transmission Sudanese company; what after load shedding at transmission side.

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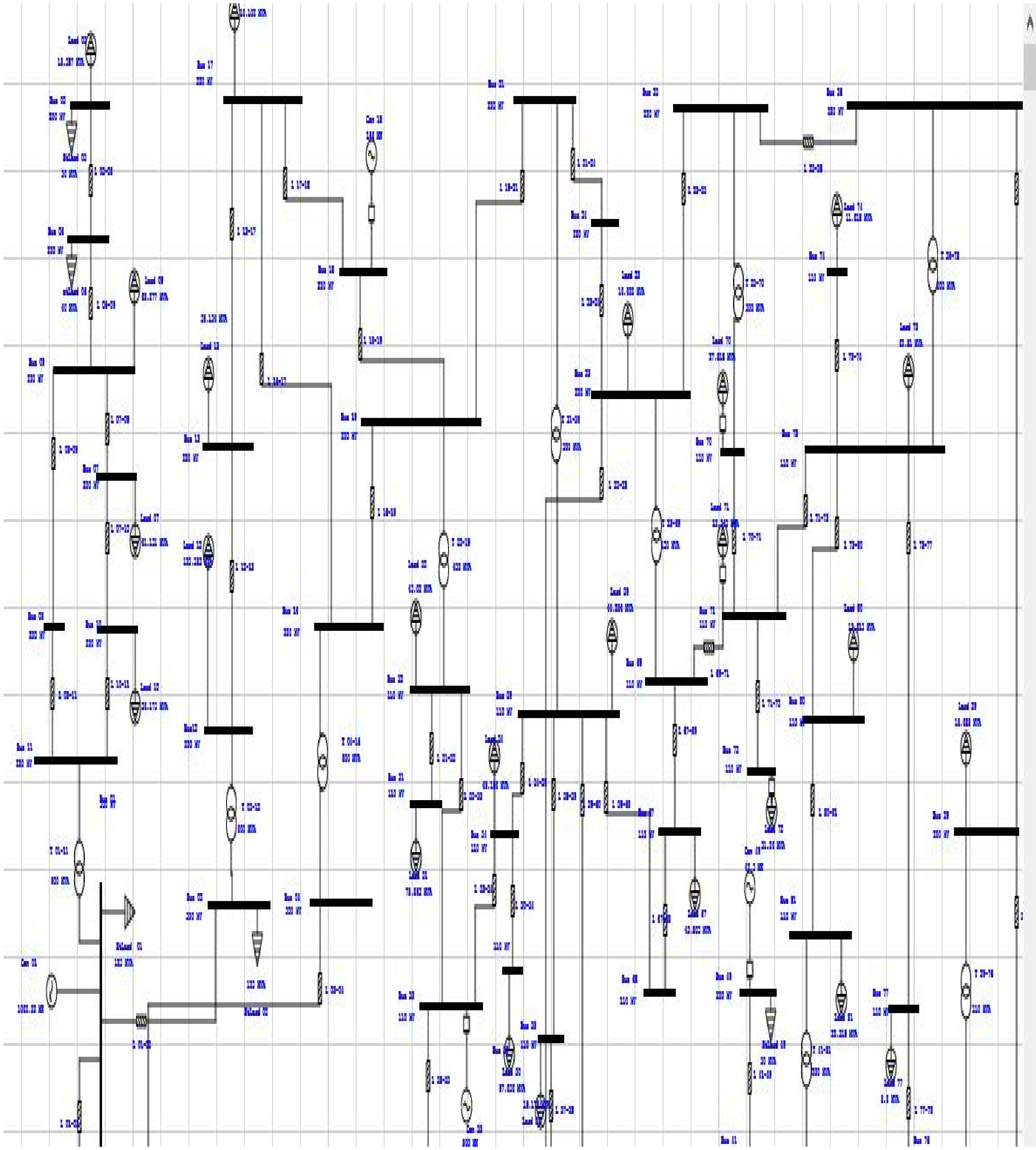
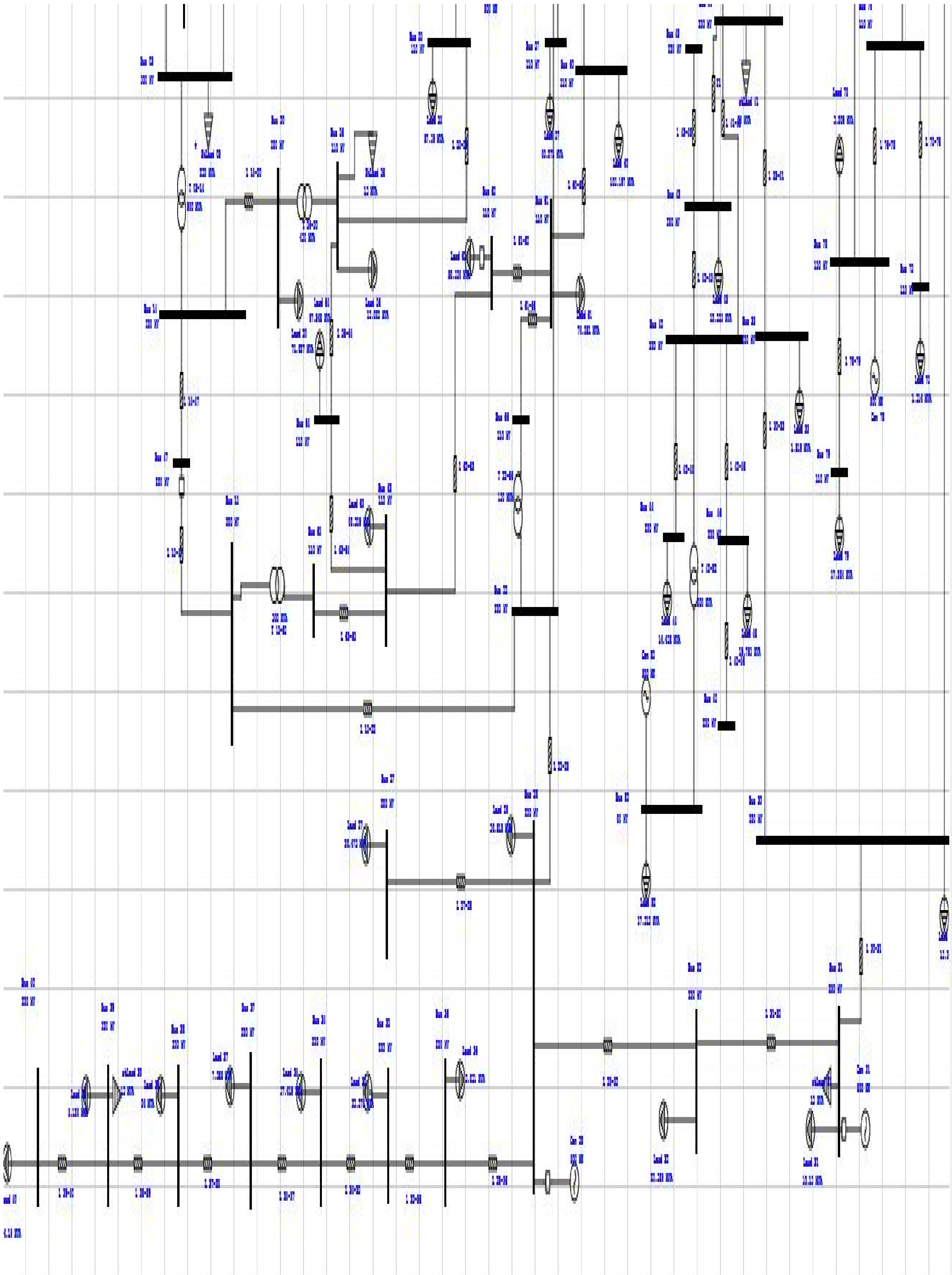
Appendix (A)

Sudanese Grid





Appendix (B)

Bus Input Data

Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus 01	500.000	1	100.0	0.0			0.000	125.000				
Bus 02	500.000	1	100.2	-3.7			0.000	125.000				
Bus 03	500.000	1	99.1	-7.5			0.000	250.000				
Bus 04	500.000	1	99.6	-8.2								
Bus 05	220.000	1	98.8	-8.9	14.360	11.483	0.000	30.000				
Bus 06	220.000	1	101.9	-8.2			0.000	40.000				
Bus 07	220.000	1	102.0	-6.5	33.456	23.961						
Bus 08	220.000	1	104.3	-5.3								
Bus 09	220.000	1	102.4	-7.9	50.320	46.148						
Bus 10	220.000	1	103.1	-3.0	29.808	20.496						
Bus 11	220.000	1	103.8	-1.7								
Bus12	220.000	1	92.7	-9.1	101.338	70.734						
Bus 13	220.000	1	97.1	-13.8	33.264	20.615						
Bus 14	220.000	1	100.3	-19.1								
Bus 15	220.000	1	99.0	-20.0								
Bus 16	220.000	1	99.1	-16.6								
Bus 17	220.000	1	99.8	-16.3	13.574	8.661						
Bus 18	220.000	1	100.0	-16.4								
Bus 19	220.000	1	99.6	-18.6								
Bus 20	220.000	1	99.7	-19.7	60.883	37.732						
Bus 21	220.000	1	99.4	-19.4								
Bus 22	220.000	1	99.1	-20.4								
Bus 23	220.000	1	99.0	-20.7	14.112	8.746						
Bus 24	220.000	1	99.3	-19.7								
Bus 25	220.000	1	96.7	-23.3								
Bus 26	220.000	1	96.8	-23.9								
Bus 27	220.000	1	99.8	-20.1	6.989	25.534						
Bus 28	220.000	1	100.0	-20.0	46.704	32.357						
Bus 29	220.000	1	98.5	-23.5	16.464	8.842						
Bus 30	220.000	1	99.9	-22.9	12.029	5.585						
Bus 31	220.000	1	100.0	-18.3	8.333	5.760	0.000	15.000				
Bus 32	220.000	1	100.8	-19.2	0.403	22.385						
Bus 33	220.000	1	100.6	-23.5	1.546	0.958						

Impedance Input Data

Impedance	Positive Sequence Impedance			
ID	R	X	Y	Unit
L 03-02	0.062651	2.67893	39.648	% in 500.000 kV base and 100.0 MVA base
L 04-03	0.194326	7.90289	25.768	% in 500.000 kV base and 100.0 MVA base
L 03-04	0.023102	0.90649	17.3708	% in 500.000 kV base and 100.0 MVA base
L 05-06	0.834795	12.7959	40.698	% in 220.000 kV base and 100.0 MVA base
L 06-08	0.948074	3.66808	63.806	% in 220.000 kV base and 100.0 MVA base
L 08-09	2.68861	6.16084	29.090	% in 220.000 kV base and 100.0 MVA base
L 09-40	2.110936	14.3907	19.089	% in 220.000 kV base and 100.0 MVA base
L 08-02	2.018645	1.96025	29.089	% in 220.000 kV base and 100.0 MVA base
L 08-49	2.34288	5.49752	26.990	% in 220.000 kV base and 100.0 MVA base
L 40-43	0.054852	2.84629	27.4588	% in 220.000 kV base and 100.0 MVA base
L 42-43	0.968005	4.36806	55.5967	% in 220.000 kV base and 100.0 MVA base
L 43-46	0.69594	3.69946	45.692	% in 220.000 kV base and 100.0 MVA base
L 43-20	0.014938	0.058387	118.132	% in 220.000 kV base and 100.0 MVA base
L 45-46	0.06289	1.022606	13.388	% in 220.000 kV base and 100.0 MVA base
L 50-32	0.0886	0.083557	10.338	% in 220.000 kV base and 100.0 MVA base
L 55-57	0.030958	1.022283	11.1.09	% in 220.000 kV base and 100.0 MVA base
L 56-57	0.36302	1.05398	15.1009	% in 220.000 kV base and 100.0 MVA base
L 56-59	0.020764	0.96595	10.829	% in 220.000 kV base and 100.0 MVA base
L 57-58	0.03461	0.33989	1.99	% in 220.000 kV base and 100.0 MVA base
L 58-59	0.52589	2.86636	23.080	% in 220.000 kV base and 100.0 MVA base
L 59-36	0.020969	0.88906	6.394	% in 220.000 kV base and 100.0 MVA base
L 36-64	0.05858	0.140636	0.2923	% in 220.000 kV base and 100.0 MVA base
L 32-38	0.38959	1.06642	14.1299	% in 220.000 kV base and 100.0 MVA base
L 38-39	0.130455	4.20473	58.1609	% in 220.000 kV base and 100.0 MVA base
L 39-60	0.08909	0.33386	9.098	% in 220.000 kV base and 100.0 MVA base
L 39-68	0.67602	3.48037	20.399	% in 220.000 kV base and 100.0 MVA base
L 60-66	0.43593	0.86902	16.094	% in 220.000 kV base and 100.0 MVA base
L 66-69	0.060495	3.49273	22.1909	% in 220.000 kV base and 100.0 MVA base
L 67-68	0.07998	4.99358	42.3598	% in 220.000 kV base and 100.0 MVA base
L 68-63	0.110382	4.064265	60.856	% in 220.000 kV base and 100.0 MVA base
L 68-64	0.76839	3.68463	40.684	% in 220.000 kV base and 100.0 MVA base
L 69-60	0.49688	2.08409	13.1564	% in 220.000 kV base and 100.0 MVA base
L 60-68	5.39688	6.46084	40.888	% in 220.000 kV base and 100.0 MVA base
L 60-69	0.68293	2.00309	30.896	% in 220.000 kV base and 100.0 MVA base
L 69-32	0.296904	26.8909	52.68	% in 220.000 kV base and 100.0 MVA base

L 70-71	0.13843	0.55579	0.496	% in 110.000 kV base and 100.0 MVA base
L 71-72	0.41529	1.66736	1.49	% in 110.000 kV base and 100.0 MVA base
L 71-73	15.8182	19.1364	1.8	% in 110.000 kV base and 100.0 MVA base
L 73-74	5.66653	15.5964	2.4	% in 110.000 kV base and 100.0 MVA base
L 73-77	10.0661	12.1777	1.14	% in 110.000 kV base and 100.0 MVA base
L 73-80	20.4198	24.7033	2.299	% in 110.000 kV base and 100.0 MVA base
L 75-76	27.601	33.4016	3.146	% in 110.000 kV base and 100.0 MVA base
L 76-78	2.87595	3.47934	0.363	% in 110.000 kV base and 100.0 MVA base
L 77-78	17.2562	20.876	1.936	% in 110.000 kV base and 100.0 MVA base
L 78-79	19.8446	24.0074	2.299	% in 110.000 kV base and 100.0 MVA base
L 80-81	44.0033	50.1992	5.203	% in 110.000 kV base and 100.0 MVA base
Z1	0.05707	0.22912	3.388	% in 220.000 kV base and 100.0 MVA base

2-Winding Transformer Input Data

			Load				Rating					
ID	kV		% Mag.	Ang.	MW	Mvar						
Bus 69	110.000	1	93.2	-23.8								
Bus 70	110.000	1	103.9	-25.5	24.730	12.738						
Bus 71	110.000	1	103.6	-25.7	11.088	5.864						
Bus 72	110.000	1	103.3	-25.9	27.821	14.253						
Bus 73	110.000	1	102.4	-26.5	56.717	26.986						
Bus 74	110.000	1	101.4	-27.4	10.886	4.058						
Bus 75	110.000	1	101.2	-25.0	0.336	1.476						
Bus 76	110.000	1	101.3	-24.9								
Bus 77	110.000	1	100.9	-26.2	7.594	4.037						
Bus 78	110.000	1	100.0	-24.8	4.704	2.238						
Bus 79	110.000	1	94.8	-25.9	14.381	9.552						
Bus 80	110.000	1	100.0	-26.9	11.021	6.539						
Bus 81	110.000	1	101.8	-25.4	18.614	12.315						
Bus 82	66.000	1	100.0	-25.1	15.254	8.604						
Total Number of Buses: 82					1553.208	1083.270	0.000	645.000	0.000	0.000	0.000	0.000

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus 01	500.000	Swing	1	100.0	0.0					
Bus 18	220.000	Voltage Control	1	100.0	-16.4	186.000			122.719	0.000
Bus 28	220.000	Voltage Control	1	100.0	-20.0	85.000			1000.000	-1000.000
Bus 31	220.000	Voltage Control	1	100.0	-18.3	148.000			1000.000	-1000.000
Bus 49	220.000	Voltage Control	1	100.0	-22.6	38.000			50.000	-50.000
Bus 53	110.000	Voltage Control	1	100.0	-26.9	76.000			1000.000	-1000.000
Bus 78	110.000	Voltage Control	1	100.0	-24.8	7.000			941.176	-941.176
Bus 82	66.000	Voltage Control	1	100.0	-25.1	2.000			1000.000	-1000.000
						542.000	0.000			

2-Winding Transformer Input Data

		Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
	Phase						+ 5%	- 5%	% Tol.			% Z	Type	Angle
T 01-11	3-Phase	900.000	500.000	220.000	21.94	99999.00	0	0	0	-3.300	0	21.9400	Dyn	0.000
T 02-12	3-Phase	600.000	220.000	500.000	23.60	99956.60	0	0	0	-9.500	0	23.5950	YNd	0.000
T 03-14	3-Phase	900.000	500.000	220.000	50.40	99999.00	0	0	0	-8.900	0	50.4000	Dyn	0.000
T 04-16	3-Phase	600.000	220.000	500.000	33.59	99978.20	0	0	0	-8.500	0	33.5900	YNd	0.000
T 15-65	3-Phase	300.000	220.000	110.000	25.68	99999.00	0	0	0	-7.500	0	25.6800	Dyn	0.000
T 21-59	3-Phase	300.000	110.000	220.000	17.88	99999.00	0	0	0	-7.800	0	17.8800	YNd	0.000
T 22-66	3-Phase	150.000	220.000	110.000	13.00	99999.00	0	0	0	-8.700	0	13.0000	Dyn	0.000
T 23-69	3-Phase	150.000	110.000	220.000	20.10	99999.00	0	0	0	-9.500	0	20.1000	YNd	0.000
T 25-70	3-Phase	300.000	220.000	110.000	15.34	99999.00	0	0	0	-9.500	0	15.3400	Dyn	0.000
T 26-73	3-Phase	200.000	220.000	110.000	14.09	99999.00	0	0	0	-8.200	0	14.0900	Dyn	0.000
T 29-76	3-Phase	110.000	220.000	110.000	15.67	42.00	0	0	0	-5.500	0	15.6660	Dyn	0.000
T 41-81	3-Phase	200.000	220.000	110.000	24.00	99999.00	0	0	0	-2.500	0	24.0000	Dyn	0.000
T 42-82	3-Phase	200.000	220.000	66.000	25.06	42.00	0	0	0	-9.500	0	25.0600	Dyn	0.000
T 52-19	3-Phase	450.000	110.000	220.000	28.95	99999.00	0	0	0	-9.500	0	28.9500	YNd	0.000
T 56-20	3-Phase		110.000	220.000	38.10	99999.00	0	0	0	-2.500	0	38.1000	YNd	0.000