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Avoidance of Blackouts using Automatic Node Switching Technique through ETAP

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Abstract— Electric power is transmitted from power generating stations to the far away load centres through high voltage transmission lines. These transmission lines interconnect the power stations and distribution grids. Besides the other few drawbacks of interconnected system one major problem that may be initiated is the blackout. In this paper an Intelligent Load Shedding (ILS) or Automatic Node Switching (ANS) technique is presented that is simulated in a very effective Electrical Transient Analysis Program (ETAP) software, to avoid the blackouts in that region of the power system facing thorough severe blackouts. Blackouts do not cause power interruption for longer time but also sacrifice the user comfort and is abviously an economical loss. The traditional already implemented techniques like under frequency and under voltage load shedding techniques may cause excessive load shedding and sudden interrruptions to most priority load. A scenario of load flow analysis is carried out for the normal operation in ETAP on real basis and then according to the inputs provided from load priority table. Through ILS non-prefered load is tripped to avoid blackout in the power utility network. The proposed ILS scheme is tested in ETAP on one of the 220kV Transmission network of Pakistan. The proposed technique is real time analysis carried out more effectively as presented in results obtained.

Index Terms— Blackout, Line Tripping, Cascading failure, Intelligent load shedding, Load Priority Table, Power system, Electrical Transient Analysis Program (ETAP)

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1 Introduction

THE blackout and cascading failures of electricity to areas start by some initial events like failure of protection system, faults due to trees, insulation breakdown and tripping of Extra High Voltage (EHV) transmission lines etc. Blackout is the short or long term or long term failure of supply as whole system or major part of the system completely collapsed [1]. The tripping of one 220kV or 500kV transmission line may caused to trip several High Voltage Distribution System due to lack of some intelligent management system [2]. Pakistan is facing such blackouts since the last few decades. Most of the transmission lines are overloaded and the power infrastructure is not sustainable. One of the techniques to avoid such major blackouts is the intelligent load shedding (ILS) system [3]. Traditional under voltage load shedding (UVLS) and under frequency load schedding (UFLS) methods have been adopted as a last line of defense for the reliable and safe operation of power system. But these existing UVLS/UFLS techniques can cause inediquate and unnecessary load shedding to some most prior load, may sacrifice user compfort and leads to economic loss as well [4].
Load Shedding is generally the amount of load that must almost be rejected from a power system to keep the other parts of the power system operational. Normally the priority load is avoided from the forced outages (load schedding) [5]. Pakistan is facing a severe issue of high short fall and therefore a load schedding of 12-16 hours occurred while 6-8 hours in cities and industrial estates [6].

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A lot of work have been done in the implementation of different techniques for the proper load shedding. One of the simplest method presented was the breaker interlock scheme [7] which is just to trip the line or part of power system for some specific duration until the some priority load is sufficiently feeded. This method is fast but is not an intelligent scheme and actually main generating breaker is interlocked with load breaker. Other technique implemented is the under frequency [4], which detect the generator output frequency and gradually reduce the load with load breaker (while main breaker is interlocked with load breaker) as the frequency decay gradually. The technique provides the stabilization or normalling the system frequency by gradual decrease in load as it thoroughly detect frequency.
Different studies have collected the major blackouts occurred in different countries. These studies provided the main reasons for these blackouts and similarly a severity level known as severity index have been evaluated for the case studies [8].The table 1, provides the complete details. The work in paper [5], decribes the use of intelligent measurement and control technology, the existing UF/UV load shedding schemes were improved. A case of a smart grid for the smart meters and home appliances was considered. Combined with the intelligent home appliances control technology, an intelligent (improved) UF/UV load shedding scheme is presented which realize the quick repose resources and the coordinated control of traditional loadschedding schemes as earlier discussed. The method of installation of some other alternative resorces for extra power generation by industries or utilities is not a good decision. The human health problems and cost of production increase [9].
M.W. Younas *et.al* [10] investigated the causes of one of the major blackout occurred in 2006 due to tripping of 500kV transmission line in Pakistan. The reasons behind the cascading failure were overloading and voltage collapse. The concept

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of smard load shedding [11] was performed through ashiyana- an improved version of direct load control (DLC) by Noman Bashir *et.al.* The adopted technique is claimed to be helpful in preventing the utility companies from social unrest and power failure but the main drawback is that it cannot prevent system from blackout or complete breakdown. Srikantha et al. [12] evaluate the technique that how peaks can be flattened if the elastic component is allowed to be programmatically controlled.

In this paper intelligent load shedding technique has been presented using simulation in ETAP software environment for the real time load flow analysis and high voltage line tripping to avoid cascading failures and blackouts. In this scheme non-preffered load (as listed in priority load table) would be cut-off from the system intelligently during abnormal conditions as system feel like sudden breakdown, faults, insulation failure etc. The proposed work has the ability to stabilize the system supply as well as the frequency. Instead of tripping all breakers those parts will be tripped by which load may be managed and priority load may not be effected. This study is performed on 220kv transmission DG-Khan to Lorlai and substations that's comes under the National Transmission and Despatch Company Limited (NTDCL) and Quetta Electric Supply Company (QESCo). The results obtained present the effectiveness of proposed methodology.

Table. 1 Major Blackouts and Impacts in World

S/No.	Blackout	Population Affected	Load Affected (Mega Watt)	Duration (Hours)
1	Brazil Mar. 11,1999	75,000,000	24.7	4
2	Iran Mar.31,2003	22,000,000	7	8
3	London Aug.28 2003	410,000	724	1
4	Italy Sept.28,2003	57,000,000	24	9
5	NorthAmerica Aug 14,2003	50,000,000	61.8	16
6	Indonesia Aug 18, 2005	10,000,000	5,000	11
7	China Jan 24, 2008	4,600,000	8,000	96
8	Pakistan Jan 24, 2016	50,000,000	1175	8
9	Pakistan Jan 15, 2016	7,210,000	4441	9

2 Implementation of Proposed Intelligent Load Shedding Scheme

Intelligent Load Shedding (ILS) is the process of optimal and fast disconnection of desired load instantly from a power system to keep the rest of system operational [11/35 ishtiaq]. Intelligent Load Shedding is sometimes called Automatic load shedding or Automatic Node Switching. The purpose of this load reduction is to avoid the whole of power system or power utility from large disturbances and power outages. ILS of real time ETAL simulation is based on maintaining the system steady state and transient stability with minimum load sched. Load shedding may be initiated due to under/over frequency, status of the circuit breakers, ground faults or reverse power etc. Intelligent load shedding may be commensed on load priority table and pre-determined/constructed stability knowledge base (SKB). Figure 1, illustrates clearly the discussion.

2.1 Main Features of ILS and alaysis within ETAP

- Knowledge based cases are carefully selected and configured
- To ensure the accuracy and completeness of knowledge base, ILS has ability to prepare and generate the training cases
- User-defined logics may easily be added
- Ability to add the system dependencies
- Online monitoring system having ability to coherently acquire the real time system data
- For the Power system that is upervised by ILS, it provides centralized distributed local control system (LCS)

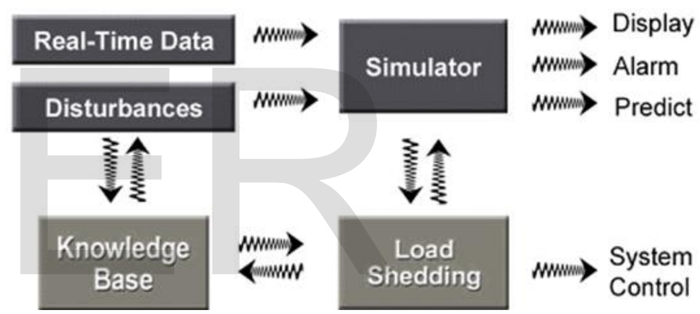

Fig.1 Block diagram of function of ILS [4]

In this paper ILS has been simulated in ETAP software which ahs some extra-ordinary fascilities to analyze the intelligent load shedding, simple load flow etc. The main feature s which may justify the effectiveness of ETAP based ILS.

- Single line diagram of a utility network can be made easily
- ILS directly works with one-line diagram containing Real-time data
- ETAP can analyze transmission lines through its sag and ampacity calculations
- ETAP ILS system has load preservation system
- ILS has reduced spin reserve requirements
- It has user-defined interface
- The priority of any load can be changed through Load Priority Table (LPT)
- It has fast reaction to an electrical fault
- ILS is based on the real operating situations such as type and location of the fault

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- ETAP gives best Load Flow Analysis of a given network
- It gives accurate Transient Stability Analysis

2.2 Over View of 220kV Transmission System of DG-Khan to Lorlai (QESCO)

Quetta Electric Supply Company (QESCo) has interconnected system of 220kV transmission system to feed its all distribution grids. The major threeinterconnected 220kV Higv Voltage regions are:

1. Daddu to Khuzdar region
2. Gaddu to Sibbi region
3. DG-Khan to Lorlai region

The total 132kV transmission lines and grid stations feed from this interconnected system are listed in a table 2.
The table also illustrates the total power supplied to each grid, load current in amperes and the power factor. From the Figure 2, it can easily be depicted that most of the load is supplied power through Gaddu to Sibbi transmission line, as it provide electricity to the Dukki, Ziarat, Khanozai, Qilasaifullah, Muslimbagh and M.Pur. The all connected loads, transformers and transmission lines are given in a single line diagram of figure 2. The ILS technique is to be applied to the selected DG-Khan to Lorlai network. The main objective is actually to trip the non-preffered load of this system as provided in the load priority table.

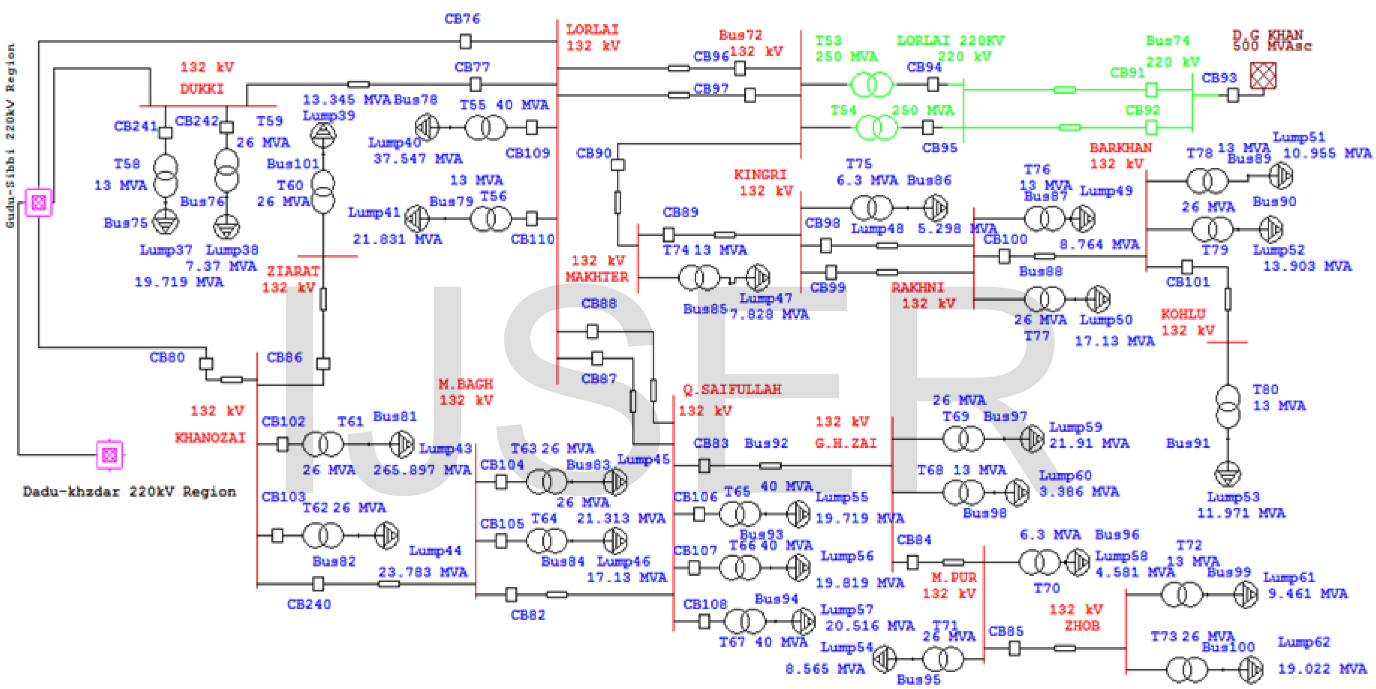

Figure 2. Single line diagram of 220kV interconnected network of QESCo.

3 Proposed Methodology

As Intelligent load shedding in modified technique of under frequency and under voltage load schedding. The methodology adopted in this research work is to apply ILS to that network which is no-preffered load and avoiding the breakdown of complete power system. In order to categorize the severity of the blackouts and obtain a practical indication of severity of a blackout, an index known as Severity Index (SVI) is used as;

$$SVI = \sqrt{(AP)^2 + (UL/GC)^2}$$

Where,

AP = Percentage of the Affected Population

UL = Un-served Load, GC = Generation Capacity

The equation (2.1) shows the equation of the severity index. This equation shows the effects of blackout on local loads and industrial demands which is the quality of a better severity index. The circuit networks of 220kV lines are designed in a special tool called Electrical Transient Analyzer Program (ETAP) which is one of the best software for power system planning, designing and operation. Following are the steps to conduct this methodology;

- To Highlight the 220kV network of the QESCO region
- Calculating the total load connected to each 220kV line
- To categorize the connected load into most-preferred and non-preferred load
- Sketching the One Line Diagrams of each lines with connected load with ETAP
- Giving preference to each load through Load Priority Table (LPT)

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Table 2. Maximum Load of 11 kV (220kV DG Khan-Loralai)

Name of grid station	Transformers Connected	Maximum Load (A)	Maximum Load(MVA)	Maximum Load(MW)
132kV G/S Loralai	T-I (26MVA)	1096	21.8	17.5
	T-II (40MVA)	1885	37.5	30
	T-III (6.3MVA)	0	0	0
132kV G/S Makhter	T-I (13MVA)	393	7.8	6.2
132kV G/S Kingri	T-I (6.3MVA	266	5.3	4.2
	T-I (13MVA)	440	8.8	7
132kV G/S Rakhni	T-II (26MVA)	860	17	13.7
132kV G/S Barkhan	T-I (26MVA)	698	14	11
	T-II (13MVA)	550	11	8.8
132kV G/S Kohlu	T-I (13MVA)	601	12	9.6
	T-I (13MVA)	475	9.5	7.6
132kV G/S Zhob	T-II (26MVA)	955	19	15.2
	T-I (40MVA)	995	19.8	15.8
132kV G/S Q/Saifullah	T-II (40MVA)	1030	20.5	16.4
	T-III (40MVA)	990	19.7	15.8
132kV G/S M. Bagh	T-I (26MVA)	1070	21.3	17
	T-II (26MVA)	860	17	13.7
132kV G/S G.H Zai	T-I (26MVA)	1100	22	17.5
	T-II (13MVA)	170	3.4	2.7
132kV G/S M Pur	T-I (6.3MVA)	230	4.6	3.7
	T-II (26MVA)	430	8.6	6.8
132kV G/S Khanozai	T-I (26MVA)	1163	23	18.5
	T-II (26MVA)	1194	24	19
132kV G/S Ziarat	T-I (26MVA)	670	13.3	10.7
132kV G/S Dukki	T-I (13MVA)	990	19.7	15.8
	T-II (13MVA)	370	7.4	6

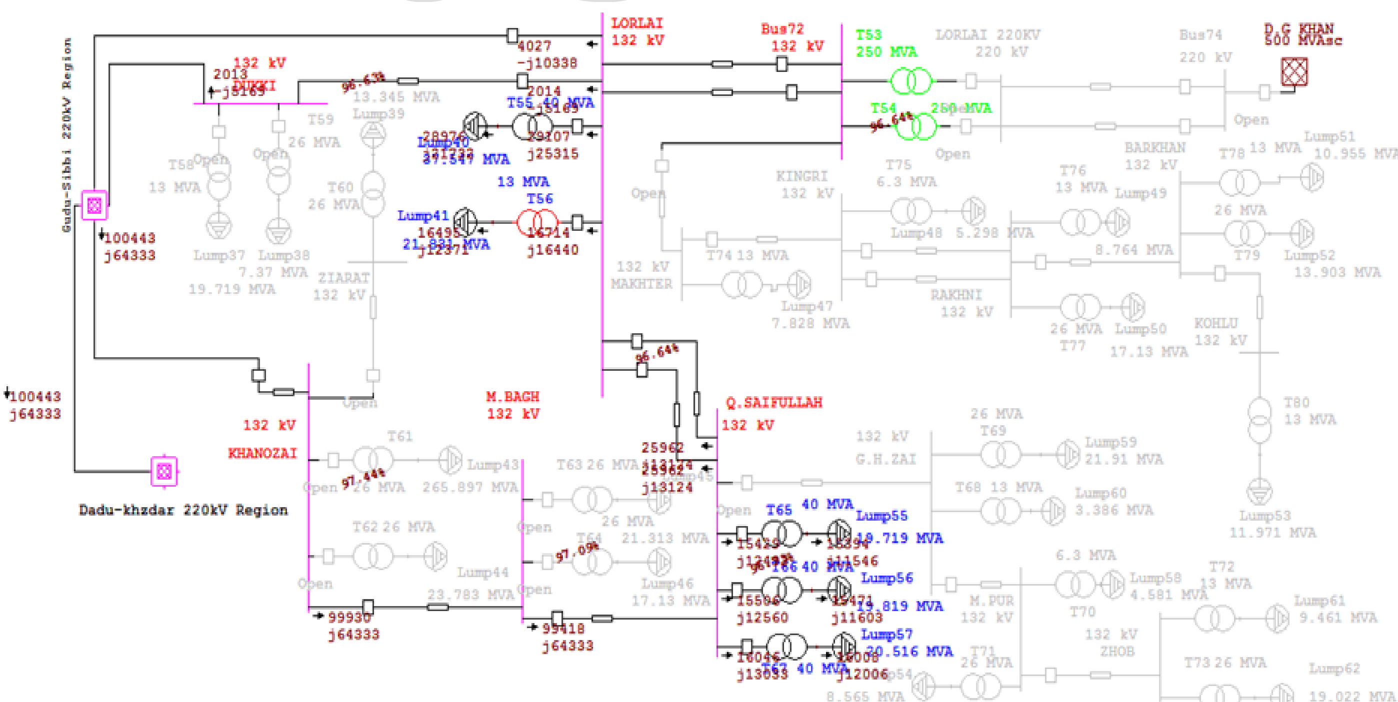

Figure 3. Implementation of Intelligent load Schedding to the 220kV network

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4 Results and Discussions

The proposed technique is implemented to the selected region for the ILS through ETAP software. The results obtained illustrates the effectivesness of this technique as the already input load in Priority load table is tripped as per instructions. During normal operation of power system the ETAP shows normal load flow as shown in figure 2. But as there is to avoid the complete breakdown or blackout, major load is disconnected or tripped from the system as shown in figure 3. The total load is reduced on the power network and hence instead of overloading the system or to collapse the voltage at all energized buses, the system remains normal in operation.

Table 3. Power shed due to ILS via ETAP

Network Topology	Peak Load (MW)	Load (MW)	Losses (MW)	Net Power (MW)	Power to be shed
With Reinforcement	1961	1698.9	108.7	1807.6	153.4 MW
Without Sibbi Reinforcement	1961	1244.6	176.7	1420.6	540.64 MW
Without Khuzdar	1961	1329.2	77.2	1406.4	554.64 MW
Without Loralai	1961	1292.3	133.7	1426	535 MW

The table 3. Clearly demonstrates the planning for ILS via ETAP. Different scenarios have been considered and impacts of tripping 220kV transmission lines as coming from three regions are elaborated. When all three transmission lines are reinforced on system, 153.4 MW load is to be shed only. While in case of neglecting sibbi line, i;e without the sibbi reinforcement the total load shed is 540.64 MW. It can be depicted form the table that without reinforcement of one of the three lines, some optimum load is to be shed as obtained from the load flow results from ETAP. Table 4, provides the total deficiencies due to the load shedding and intelligent load shedding. Since in this paper ILS is claimed to be more helpful performed through ETAP, it decreased the system load schedding deficiencies. This table also illustrates the transformers, load that is shed and 132kV grid stations that would be effected. The 11kv feeders that are tripped automatically as there will be a chance of sudden breakdown. The ILS operated in ETAP will look at non-preffered load and will disconnect that load from the system. Like here in Table 4, the total load connected 11kv feede that is trippedr, poer transformers and location has been provided.
The load flow analysis carried out in ETAP is presented in figure 3. This also show the tripped circuitry and 11kV feeders according to the proposed method. The most priority load is feed from the other 220kV transmission lines as the 220kV line of DG-khan to Lorlai is tripped. One main drawback will be to control the stability of the system that will be challenged during sudden breakdown of 220kV lines. But the ILS through ETAP should be so fast to avoid blackout and to trip the non-preffered load before the shifting of major load on other lines. So actually ILS method is adopted to avoid such balckouts as it tripped load instead of shifting on other transmission lines or grids.

Table 4. 11kV Load Shedding ofproposed 220kV DG-khan to Lorlai Network

Name of 132 kV Grid station	Transformer Connected	Max.load (MVA)	Max.load (MW)
Makhter	T-I (13MVA)	7.8	6.2
Kingri	T-I (6.3MVA	5.3	4.2
Rakhni	T-I (13MVA)	8.8	7
	T-II (26MVA)	17	13.7
Barkhan	T-I (26MVA)	14	11
	T-II (13MVA)	11	8.8
Kohlu	T-I (13MVA)	12	9.6
Zhob	T-I (13MVA)	9.5	7.6
	T-II (26MVA)	19	15.2
Muslim Bagh	T-I (26MVA)	21.3	17
	T-II (26MVA)	17	13.7
Zai	T-I (26MVA)	22	17.5
	T-II (13MVA)	3.4	2.7
M Pur	T-I (6.3MVA)	4.6	3.7
	T-II (26MVA)	8.6	6.8
Khanozai	T-I (26MVA)	23	18.5
	T-II (26MVA)	24	19
Ziarat	T-I (26MVA)	13.3	10.7
Dukki	T-I (13MVA)	19.7	15.8
	T-II (13MVA)	7.4	6

The total load at 11kv feeders tripped is about 214.7 MW (268.4 MVA at 0.8 p.f) to avoid blackout while the initial load connected to the 220kV DG-khan to Lorlai network is 304.96 MW or 381.2 MVA. It is evaluated that only 90.26 MW load will be served during ILS while rest of the load will be cutoff from main utility grid. The severity index (SVI) for the blackouts that may occure on the system will approximately equal to the population affected. Since during ILS the non-preffered load is switched off from supply so the blackout will be avoided and hence system SVI will also be reduced.
The number of customers effected during ILS depends upon the initial scenarios of the network, its complexity, connected grids, number of transmission and distribution lines etc. greater the complexity larger will be the number of population effected. Similarly if the total number of customers connected are disconnected and the ratio of disconnected load in MW to total generation in MW is one or near to one then the severity index of this blackout will be equal to 100.
The results obtained demonstrated that through ILS the net chances of blackouts reduced. The major load is intelligently disconnected from the system and preffered load will remain connected to the system without interruptions and disturbances. The frequency increase during switching off load from

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the network but it can be handelled through shifting load from the previous network or transmission line to the other line or grid which has the capacity to take extra load without overloading or tripping. Also it should be noted that shifting load from one line to other will enhance the chance of voltage collapse so by proper planning and gradual and fast shifting it can be avoided.

5 Conclusion

During the Blackouts major or complete load is tripped due to system disturbances in interconnected system and whole generation is shutdown for several hours to several days. Existing load shedding techniques avoid the system from the blackouts but may create another disturbances in the system. Instead of adopting such schemes a new technique of intelligent load shedding (ILS) is propoed wchich is simulated through ETAP software. The case study one of the 220kV transmission network of Quetta Electric Supply Company (QESCo) was taken. The load flow analysis through ETAP is carried out when all the load is connected to the network and then through ILS technique the non-preffered load is disconnected as provided by Load Priority table. The results obtained clearly demonstrated that with suddent selected load interruption the blackout is avoided and most important load is supplied power without any disturbance or interruption. The ILS is planned mechanism and its duration depends upon the utility planning team.

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