Optimal re-planning of a 30kv distribution network with DG penetration

Based on economic dispatch and optimal load flow

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Abstract

In this paper an optimal and economic dispatch study will be performed for re-planning a large section of Libyan Electrical distribution network, that include Electrical power plant ,considering distribution generation (DG) penetration method instead of a conventional re-planning methods, such as the expanding and adding methods that needs efforts and time.

The new approaches of electrical distribution system of economic operation and replanning are the most efficient and interested to the electric power utilities now days.

The availability of high performance software's such as the MATLAB and NIPLAN helps in redesigning and replanning of electric power system for enhancing performance and solving system problems.

Libyan electric distribution networks are suffering many problems of voltage limits violation, high system losses and low system performance.

The optimal power flow (OPF) with economic dispatch (ED) methods will be used to show the benefits of using DG penetration.

Alzahra 30KV electric system is taken as the case study including AL Zahra power plant, with different operation cases are considered includes the operation of the network as an isolated grid, considering DG penetration during peak loads with OPF analyses.

This study shows the great effect of DG pentration with ED and OPF methods for reducing fuel costs and power losses as well as increasing the power transfer for system transmission, the reduction of 14.5% of fuel consumption is achieved, and about 70% of total power losses in the studied network is reduced with an excellent performance of system voltage profile and line loadings.

Key words: DG, optimal Re-planning, OPF, Economic Dispatch, NIPLAN

I. INTRODUCTION

The optimal power flow (OPF) has had a long history in its development it was first discussed 1950s in literature and then by CARPENTIER in 1962, then it takes a long time to become a successful algorithm that could be applied in everyday use by the aid of fast computers and software's [1]. Current interest in the OPF algorithm around its ability to solve for the optimal solution that takes account of the security operation of the system. Optimal Power Flow (OPF) is an optimizing tool of power system operation analyses for scheduling and energy management. Use of the optimal power flow becoming more important because of its capabilities to deal with various situations of power system operating modes.

This problem involves the optimization of objective functions of Optimal Power Flow (OPF) for power system models, which are the main functions of Power Generation Operation and Control, and for system power losses.

The aim of this paper is to propose an Optimal Dispatch calculation of ALZHRA power plant and a study its optimal replanning with its 30kv network based on distribution generation (DG) penetration methods.

II- PROBLEM FORMULATION

Most of Libyan electric network parts has not been studied and analyzed for optimal and economic dispatch operation. AL Zahra power plant is feeding a 30KV system network which connected to the Libyan Electric Grid needs to be studied and analyzed for economic dispatch and optimal operation at different operating conditions and modes.

The network will be simulated using the objective function for generators heat rate equations and power loss function of the network, by applying Larangian Optimization Algorithm, Newton-Raphson method, and

III-SYSTEM OBJECTIVE FUNCTION

For optimization procedure, objective functions are needed to be minimized according to system variance parameters,

so there will be two main objective functions will be considered:

A .THE OBJECTIVE FUNCTION OF ECONOMICAL DISPATCH

For economic dispatch the objective function should be dealing with heat rates or cost rates. The generators heat rate is performed according to system testing results, or during restarting of the plant generators after maintenance periods.

Data for Al-Zahra plant generators are given by National Scientific Research Association (NSRA) of Libya through their research studies [10].

The relation between power out puts in MW and MBTU/h are performed as shown in table (1), using Excel software for curve fittings the heat rate curve is shown in figure (1), which similar for all three power plant units of the chosen system.

Table (1) the MBTU/h vs output power in MW

H MMBTU/ MWh	P MW	Heat rate MBTU/ h
20.87	15	5261
28.27	10	7124
20.87	15	5261
17.25	20	4347
15.12	25	3811
13.75	30	3465
12.81	35	3227
12.13	40	3057
11.8	45	2973.6
10.7	50	2696.4

Also the heat rate equation are performed by Excel:

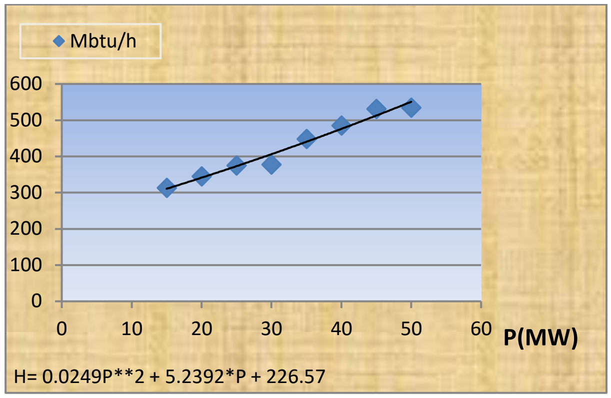

Fig (1) Heat rate curve for each thermal power plant units of the system

The heat rate equations for each generator are found to be:

$$\mathbf{H} = 226.57 + 5.2392\mathbf{P} + 0.0249\mathbf{P}^2 \quad (1.1)$$

In the form of $\mathbf{H} = \boldsymbol{\alpha} + \boldsymbol{\beta}\mathbf{P} + \boldsymbol{\gamma}\mathbf{P}^2$

Where $\boldsymbol{\alpha} = 226.57$ is constant in MBTU/h

$\boldsymbol{\beta} = 5.2392$ MBTU/MWh

$\boldsymbol{\gamma} = 0.0249 \quad \frac{MBTU}{(MW)^2\, h}$

P= power output in MW

H= heat rate in MBtu/h

B- THE OBJECTIVE FUNCTION FOR SYSTEM POWER LOSSES

The power loss equation can be given in a quadratic form as [2]

$$\boldsymbol{F(P_G) = \sum_{J=1}^{NG}(c_i P_{G1}^2 + b_i P_{Gi} + a_i) + \big(g(p_i)\big) + \mu\big(\mu(p_i)\big)}$$

(1.2)

where $\boldsymbol{a_i}$, $\boldsymbol{b_i}$, $\boldsymbol{c_i}$ Are constants of the polynomial.

Also P_{loss} should be expressed in terms of system parameters and given by using the B matrix [2] which is defined by Stott decoupled power flow [2] as shown in the loss equation is given by:

$$\mathbf{P_{loss} = P^T[B]P + B_0^T P + B_{00}} \quad (\mathbf{1.3})$$

P = vector of all generator bus net MW

[B] = square matrix of the same dimension as **P**

B, = vector of the same length as **P**

Boo = constant

Equation (1.3) is presenting the objective function of the system power and used for optimal power flow with system inequality and equality constraints for voltage limits, active power limits, and reactive power limits as well as the plant generation limits.

Software NIPLAN is used for system simulation and analysis based OPF and ED.

IV- DESCRIPTION OF THE CHOSEN DISTRIBUTION SYSTEM

The system chosen is consists of:

1) Voltage source power of 3 generator connected to 30VK bus
2) Transformers 220/30 kv substation
3) Transformers 30/11 kv to the loads
4) Overhead lines & Underground cables.
5) Bus bars 30 kv.
6) Bus couplers & Bus sections
7) Loads.

The system configuration in fig (2).

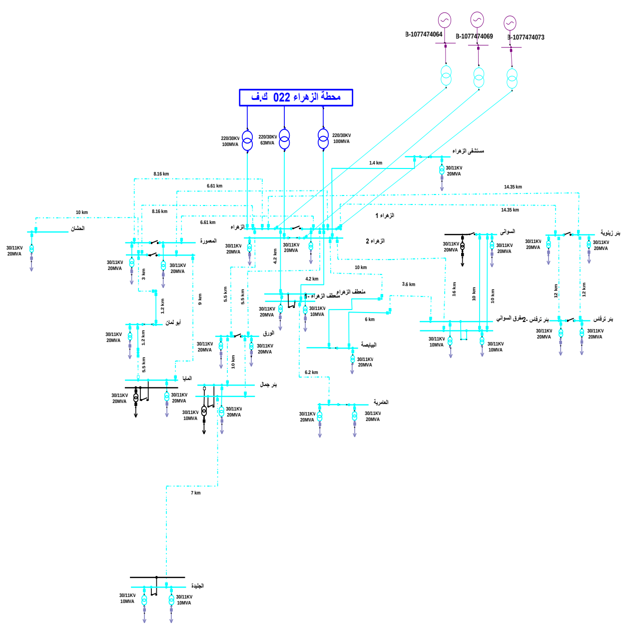

fig (2) system configuration

V- Normal and Optimal Power Flow Applications and Case Studies

To implement OPF for an electrical network used in this research study Alzahra 30KV power plant and its 30kv circuit is considered.

ALZAHRA 30kv network consists of 20 busbars the main 30kv busbar connected to 220kv system through three (220/30) kV transforms also a three gas-turbines of 47.5 MW size each are connected to the same 30KV busbar, which

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ered as the main bus bar.

A-Application Normal Optimal Load Flow (OPF) for the System Analysis

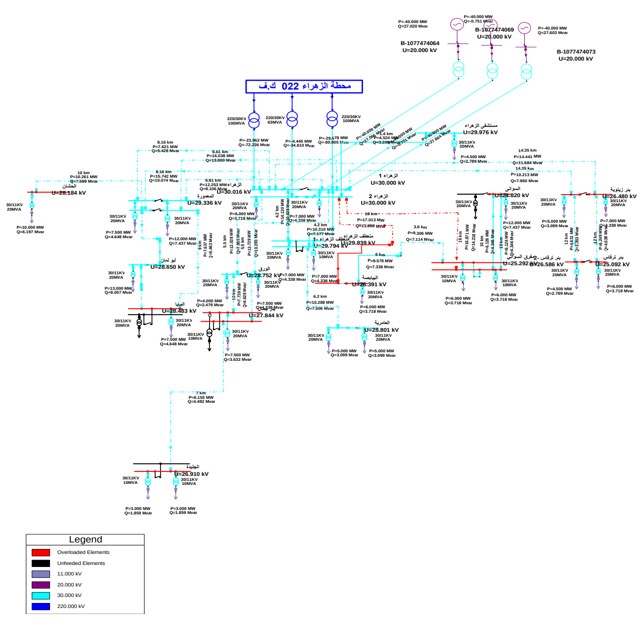
In this case the normal OPF is applied and the results are shown in table (2)

Table (2) the normal optimal load flow for Alzahra power generators are connected

Iteration data										
Iterations:	4									
Mismatch:	4.00E-05									
From	To	P Loss	Q Loss	P Imp	Q Imp	P Gen	Q Gen	P Load	Q Load	Gen. Cost
Area/Zone	Area/Zone	MW	MVar	MW	MVar	MW	MVar	MW	MVar	Curr. Units
Network		10.385	48.452	58.885	205.732	178.885	151.86	168.5	103.408	1427.926
Area 1		10.385	48.452	0	0	178.885	151.86	168.5	103.408	1427.926
Zone 1		10.385	48.452	0	0	178.885	151.86	168.5	103.408	1427.926
Un		P Loss Lin	Q Loss Lin	P Loss Tra	Q Loss Transformer					
kV		MW	MVar	MW	MVar					
30		8.483	12.394	1.002	18.079					
220		0	0	0.9	17.98					
Overloads										
Nodes (low	%									
المايا	94.94									
N1077349	94.62									
N1077349	94.52									
الحشان	93.95									
N1077349	92.88									
N1077349	92.87									
بئر جمال	92.81									
N1077349	92.48									
بئر جمال 30-	92.22									
بئر زينوبة 2-	91.88									
N1077364	90.28									
الجليدة	89.7									
N1077349	89.7									
بئر ترفاس 2-	88.62									
بئر زينوبة	88.27									
البيابصة	87.99									
البيابصة	87.97									
N1077364	86.52									
N1077349	86.2									
N1077349	86.19									
N1077349	85.62									
مفرق السواني	84.31									
مفرق السواني	84.3									
بئر ترفاس	83.64									
السوانى	82.73									
Elements	%	Type								
L1077364	141.77	Line								
U	129.99	Line								
1	129.05	Line								

The results for system analysis shows that the system suffering voltage violation for most bus bars and high loadability of some lines as shown in table (2).

Figures (3) also shows the system weaknesses on the one-line diagram of the Net Work.



with red lines on the single line diagram.

The solution for such system problems by conventional methods will result maney changes of system configuration that costs efforts and money beside the time consuming that delaiy the economic growth of whole area.

B- Optimal Power Flow Applying DG for Enhancing System Performance

Instead of applying conventional methods for system problems solution, the DG units will be applied to replanning the network, first using the optimal load flow and economic dispatch withe placing DG units at the buses of low voltage profile to estimate the sizes of DG needed, this procedure will be repeated to find out the best size and location that satisfy the conditions of voltage regulations and reducing the power losses.

The best DG size and location is estimated and shown in figure (4), where three DG units are added to the far end bus-bars, which are: DG connected to Mufreq-eswani Bus-Bar with a 28.346 MW and 10.217MVAr and two connected to Bir-Terfas Bus-Bar with total power of 17.175 MW and 12.117MVAr

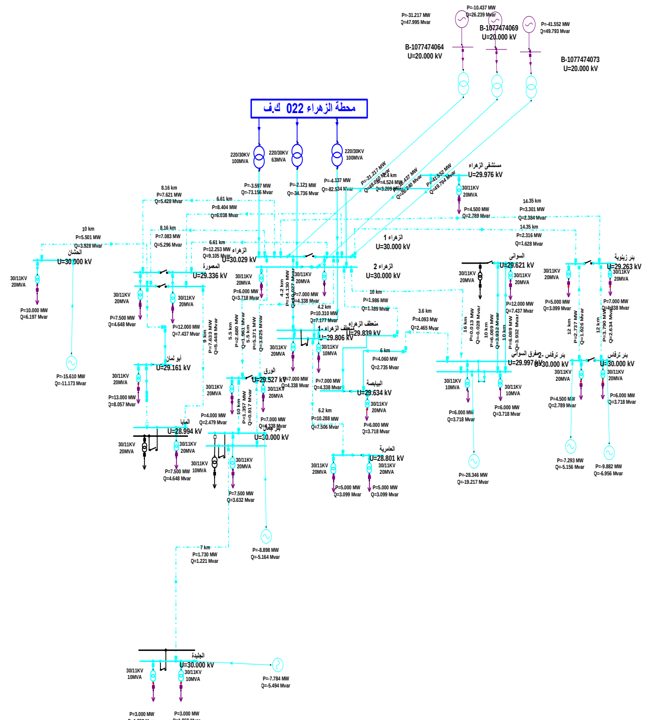


Fig (4) show the configuration line diagram with generators connected

Applying the OPF and ED analysis the results are shown in table (3)

Table (3) the simulation results with DG penetration

From	To	P Loss	Q Loss	P Imp	Q Imp	P Gen	Q Gen	P Load	Q Load	Gen. Cost
Area/Zone	Area/Zone	MW	MVar	MW	MVar	MW	MVar	MW	MVar	Curr. Units
Network		3.215	32.894	10.699	207.169	171.715	136.302	168.5	103.408	1185.578
Area 1		3.215	32.894	0	0	171.715	136.302	168.5	103.408	1185.578
Zone 1		3.215	32.894	0	0	171.715	136.302	168.5	103.408	1185.578
Un		P Loss Lin	Q Loss Lir	P Loss Tra	Q Loss Transformer					
kV		MW	MVar	MW	MVar					
30		1.416	-0.83	0.96	16.98					
220		0	0	0.838	16.744					

From table (3), the result shows that problems of the voltage violations are solved and voltage at buses is within the limits as shown in figure (4)

Also the total losses are reduced to 3.215MW which is reduced by 68.68% of the base case the fuel cost reduced to be 1185.578 MBTU/hr. the reduction is 16.97 %. The reduction in fuel cost is 427.923 MBTU/hr. ,that can transferred to Dinar/hr.
Also Fig (5) shows the voltage profile curve of the system busbars**.**

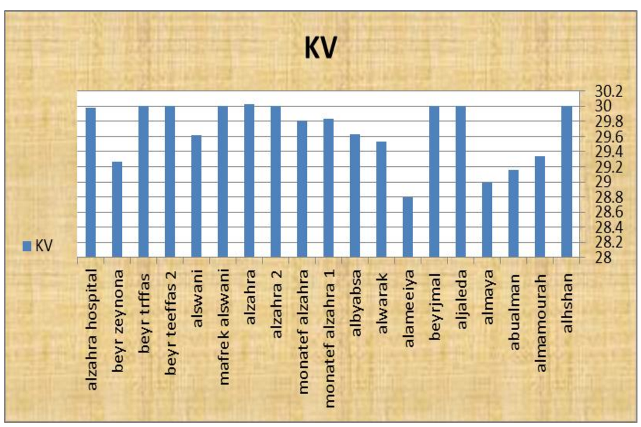


Fig (5) shows the voltage profile curve of the system busbars

VI-AL-Zahra Electric Network as an Isolated Grid Case Study
In this case whole grid is isolated from the main Libya Electric Network.
In this case the grid is fed from the local Al-zahra power plant with adding the DG units on the 30KV busbars as shown figure (6), where another tow DG units are added to Alhashan Bus-Bar and Bir-Jamal Bus-Bar besides the three DG added to the last case, where the optimal search procedure is repeated to reach this result.

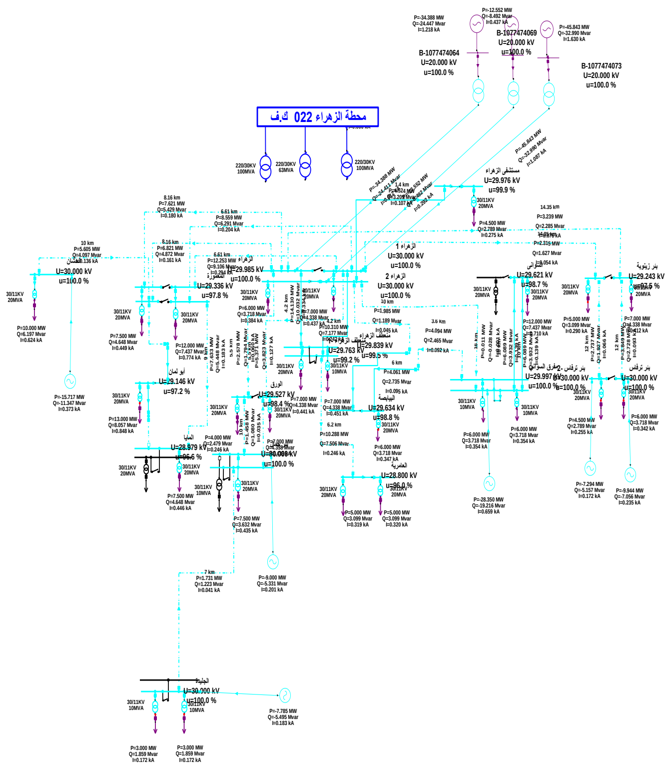


Figure (6) shows the network configuration as an isolated network

Applying the OPF and ED analysis, table (4) shows the results.

Table (4) isolated system OPF analysis

From	To	P Loss	Q Loss	P Imp	Q Imp	P Gen	Q Gen	P Load	Q Load	Gen. Cost
Area/Zone	Area/Zone	MW	MVar	MW	MVar	MW	MVar	MW	MVar	Curr. Units
Network		2.373	16.123	58.393	41.483	170.873	119.531	168.5	103.408	1251.501
Area 1		2.373	16.123	0	0	170.873	119.531	168.5	103.408	1251.501
Zone 1		2.373	16.123	0	0	170.873	119.531	168.5	103.408	1251.501
Un		P Loss Lin	Q Loss Lir	P Loss Tra	Q Loss Transformer					
kV		MW	MVar	MW	MVar					
30		1.412	-0.832	0.96	16.955					

The results shows that

- The power plant of Al-Zahra power plant units operate at its 80% range limits
- The total DG units generates a 77MW to the load (peak load is considered)
- The total losses also reduced by 77.14%

- The fuel cost is decreased to be 1251.501MBTU/hr. by 176.425 MBTU/h only which is 12.356%. and this due the depends of the system on the local power plant units instead of local grid.
- Isolated Operation could accomplished with better performance of the system and best voltage profile.

Figure (7) shows the comparative results of system power losses between different operation scenarios

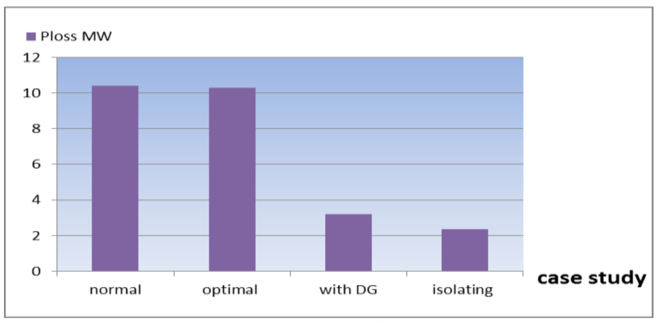


Fig (7) a comparative results of system power loss

Also figure (8) shows the voltage profile for different operation senarios

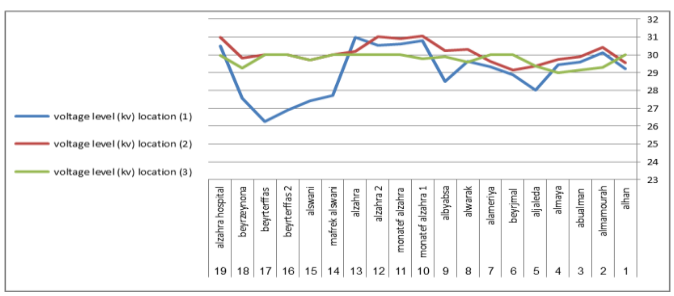


Fig (8) system voltage profiles different operation scenarios

VII- CONCLUSIONS

In this paper both economical dispatch and optimal power flow were considered based on distribution generation penteration (DG) in the network.

The study shows the benefits of using new techniques for power system replanning and redesign, and for solving system suffered problems, and enhancing system performance.

Many case studies are performed considering DG pentration with case Economic dispatch procedure which results in the following benefits:

• The power losses are extremely reduced by more than 70% and reactive power losses is reduced by 32%.

• The fuel cost for the power station is reduced by 14.5%with economic dispatch.

• The imported power from the main circuit is also reduced by 95% which reduces the main transmission losses, and increasing its power transition ability.
• The overall voltage profile is enhanced to be within the standard limits
• The grid is stable with minimum losses when it is isolated.
Isolation operation is found to be the best solution and it can be applied to solve the over all National Grid problems and reduces the Black Out events.

VIII- AEFERENCE

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