Voltage stability of the Libyan network after its enhancement by new mobile generators.

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***ABSTRACT*- The conflict that took place in Libya in 2011, has greatly affected the electrical power network and resulted in loosing major transmission lines and loosing few generating units. As result to that the operation mode of the Libyan network mostly is being at the emergency and alert modes. Any sound disturbance lead to losing any line or generating unit may in fact makes the system unstable, if load shedding is not promptly taken. One of major Libyan network weakness is the long distance between its main three regions, Southern, Western and Eastern, and that no power stations located at southern region. This situation has made the problem of voltage instability be more severe in Southern region. As electric power to all consumers should be maintained quickly and the severity of voltage instability should be contained, Mobile and small generation units were proposed to be utilized at different locations of Libyan network. This solution is considered as a fast and temporary solution.**

This paper discusses voltage instability problem within the Libyan Network and presents the network voltage stability improvement achieved by enhancing the network with small and mobile generation units. The small and mobile generation units are connected at selected points on the network. The selected points were identified as the most weakened buses and regions. The mobile units were connected for the attainment of optimized solution. Moreover, this solution was proposed as it can solve not only the voltage instability problem, but it will also solve the inadequacy in generation issue by circulating additional power within the network. Hence, reduce the period of load shedding.

***KEYWORDS*- Mobil Units, Voltage Stability, Eigen Value, QU, PU Curves.**

1. INTRODUCTION

The Libyan electricity network is divided into three geographical regions, Western, Southern and Eastern region. As shown in figure 1, western zone consist of three sub-zones or islands (Central, Tripoli & West), while Eastern zone consist of two subzones, i.e. Albida and Benghazi). The western and eastern areas are connected through single circuit 400KV (KALEJ4 - RLNOF4) and double circuit 220 KV (SIRST2 - RLNOF2). Whereas the Western and Southern regions are linked via three lines which are single circuit 400 KV (HOMSW4 - GMMR4) ، double circuit 220 KV (BNJEM2 - ZAMZM2) and double circuit 220 KV (BINWLID2 -GMMR2). Internationally, Libya is connected to the Egyptian network from the eastern border through high voltage line (TOBRK2 - SALLUM2) 220 KV, while the western border is connected to the Tunisian network through two high voltage lines (ABOKMASH - MEDENINE), (RWAYS2 - TATAWIN) 220 KV.

Load growth in Libya usually grown at normal rates, however since 2011 the growth of load may be considered as not normal. This is due to the random use of electrical power and to the exodus happened as a result of war. The load usually records a noticeable increase during the summer season due to the excessive demand of the air conditioners. In addition to that, a reduction of about 15% of the gas turbine units occurs during summer, which is known as (temperature control). Consequently, the power factor value would be plummeted to the extent that causes a considerable voltage collapse.

In this paper the behavior of the network under different operating scenarios, has been studied focusing on the determinants of voltage instability. The paper will examine the network when enhanced by several small mobile generating units planted over a wide geographical area of Libya. Few measures were considered in this paper such as, adjustments through changing the transformation steps, shifting some of the network links or installation of new mobile units.

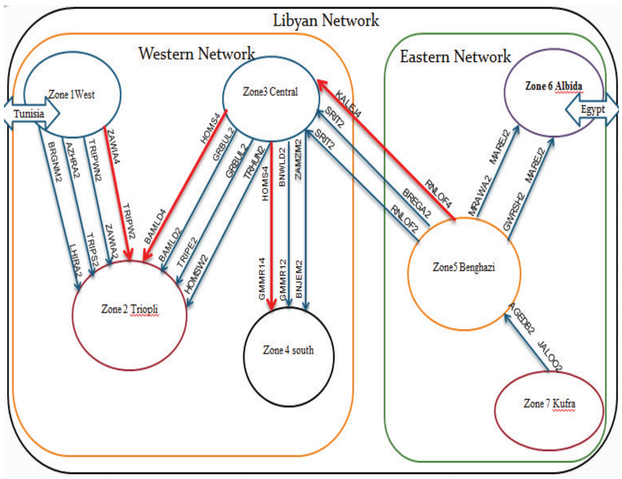

Fig. 1. The seven sub zones of the Libyan network.

2.Voltage Stability:

Voltage stability study is conducted to assess the ability of a power system to maintain steady voltages at all buses in the system under normal operating conditions, and after being subjected to a disturbance. Phenomenon of instability reveals itself in the form of a progressive fall or rise of voltage of some buses. Voltage instability of a network leads to a loss of load in the area where voltages reach unacceptably low values, or a loss of integrity of the power system [2].

While the most common form of voltage instability is the progressive drop in the bus voltages, the possibility of overvoltage instability also exists. It can occur when EHV transmission lines are loaded significantly below surge impedance loading and under excitation limiters prevent generators and/or synchronous condensers from absorbing the excess reactive power. Under such conditions, transformer tap changers, in their attempt to control load voltage, may cause voltage instability [2].

The factors that may affect voltage stabilityare:

- Reactive power capability of synchronous generator;
- Automatic voltage control of synchronous generator;
- Loads;
- Under-Load Tap Changer, and.
- Compensation Devices [2].

3. Causes Of Voltage Instability in Libya

I. Delaying the maintenance of the damaged transmission lines during the crisis.
II. Significant and un-controlled increase in loads after 2011.
III. Disturbing the overhauling schedule of the generating units that led to minimizing the generating capacity.
IV. Rescheduling to the ongoing and planned new power plants projects.

4. Methadology and Objectives.

- Address the points that considered as the weakness points of the Libyan network. The focus will be on southern region.
- Then the effect of planting the small mobile units in different locations is studied.
- The results are summarized for optimum locations of these units to enhance the network performance to reach the most possible efficient network operation.

5. Analysis and results.

Load flow and voltage stability results are presented in this section. The software used is Neplan (power simulation program).

The evaluation considered different network connections, maximum load during year 2013, and then when the network enhanced by the mobile units. The evaluation was based on GECOL data for year 2013 at peak load.

In all cases the aim is to find:-

- Self-Sensitivities of bus bars.
- Eigen value.
- Q-V curves.
- P-V curves.

The study will attempt to identify the capability of the network towards an expected loads growth especially during summer time.

To analyze voltage stability by using NEPLAN, following modules must be invoked and the list of parameters should be determined:

- Load flow.
- Voltage stability.
  - o Self-Sensitivities of busbars.
  - o The Eigen value.
  - o P-U curves.
  - o Q-U curves.

A. Load flow Analysis during maximum load :

I. Load Flow result at maximum load with no mobile units connected to the network.

The load flow study is an initial requirement for voltage stability study. Neplan program is used to find the state of the network during maximum loading and branch loading for the all of the scenarios being studied.

The results are summarized in figure 2 below where the maximum generation and maximum load are at the Western region. One can notice the high amount of reactive power and non existence of power generation at Southern region.

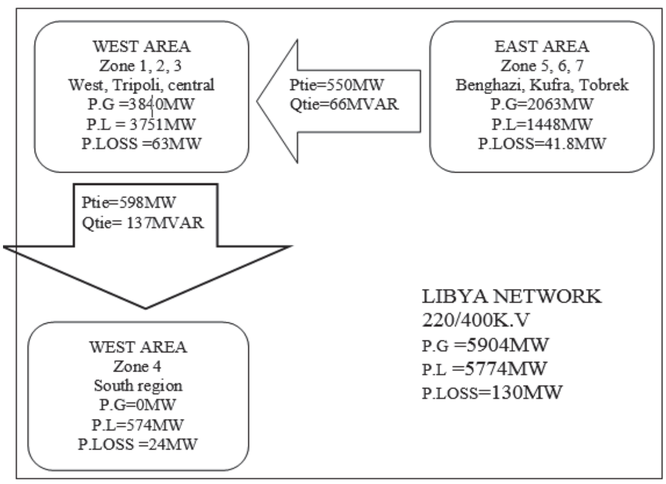

Fig. 2. Load flow results case1; (maximum load and no mobile units).

II. Load Flow result at maximum load and the network being enhanced by new mobile units.

Due to the increased demand and the need to a quick remedy to the Libyan network, approximately 130 small mobile generation units with total capacity exceeds 400 MW were planted over the Libyan network. 62 mobile units with total capacity of 160 MW were planted in Southern region. The rest of mobile units planted in Western region. The aim was to fulfil the need to the electricity and to preserve the voltage stability of the network. List of these small units and their capacity are shown in table 1 below.

TABLE 1

Power Mobile Generation Units planted in Libyan network.

Substation Name	zone name	No. of Units	Power Operation [MW]	Total Power [MW]
SAMNO	South	4	20	80
AIN ZARA	Tripoli	2	19	38
ZLETIN	Central	2	24	48
HOMSP	Central	4	24	96
UM-JDAWEL	South	58	1.4	80
BAMLD	Central	58	1.4	80

The results are summarized in figure 3 below where the maximum generation and maximum load are still at the Western region, and 160 MW are planted at the Southern region. The results show that minimizing in power losses.

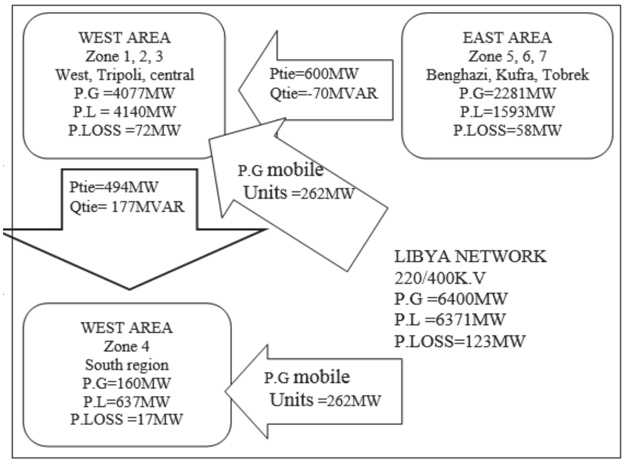

Fig. 3. Load Flow result at maximum load when the network is enhanced by new mobile units.

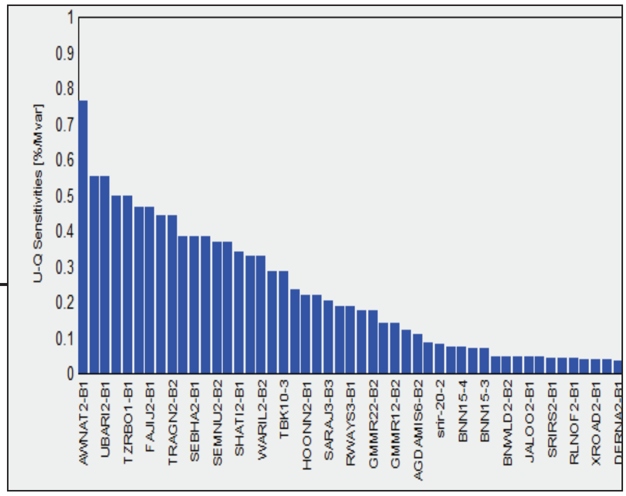

Fig. 4. busbar self-sensitivity at maximum load without mobile generators.

B. Voltage stability before and after the addition of mobile units genrators.

I. Self-Sensitivities of bus bars.

Sensitivity analysis calculates the relation between voltage change and reactive power change.
Positive sensitivities mean stable operation; i.e. the smaller sensitivity index, the more stable is the system.
Thus the higher the value of busbar sensitivity index the lower the stability of the system.

- Positive sensitivity = stable system (more small, more stable).
- Negative sensitivity = unstable system.

Figures 4&5 illustrates graphically the most sensitive busbars before adding the mobile units (fig 4), and after adding the mobile units (fig. 5)

It is quite obvious from fig.4 that buses (Awant-2, ubari-2 and turbo-1) at south region specially are more sensitivity to change in reactive power from other busbars. However the busbars at Southern region has showed higher sensitivity.

After adding the mobile unites the most sensitive busbars still the same i.e. (Awant-2, ubari-2 and turbo-1) at Southern region but the degree of sensitivity becomes less. However comparing both figures the improvement in busbars sensitivity is very obvious and that the busbars at Southern region still showing higher sensitivity to the change in reactive power.

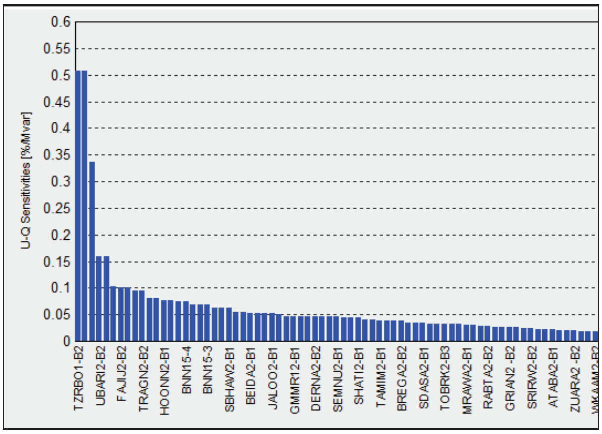

Fig. 5. busbar self-sensitivity at maximum load when enhanced system by new mobile units.

II. The Eigen value.

λ1, λ2, ……,λn are the diagonal elements of diagonal Eigen values matrix, $\mathbf{J_R}$ which is the reduced Jacobian matrix of the system.
If $\lambda i > 0$, the i^{th} modal voltage and the $\boldsymbol{i^{th}}$ modal reactive power variations are along the same direction, indicating that the system is *voltage stable*.
If $\boldsymbol{\lambda_i < 0}$, the $\boldsymbol{i^{th}}$ modal voltage and the $\boldsymbol{i^{th}}$ modal reactive power variation are along opposite directions, indicating that the system is *voltage unstable*.
The magnitude of each modal voltage variation equals the inverse of $\boldsymbol{\lambda_i}$ times the magnitude of the modal reactive power variation. In this sense the magnitude of $\boldsymbol{\lambda_i}$ determines the *degree of stability* of the $\boldsymbol{i^{th}}$ modal voltage.
The smaller the magnitude of positive $\boldsymbol{\lambda_i}$, the closer the $\boldsymbol{i^{th}}$ model voltage is to being unstable. When $\boldsymbol{\lambda_i=0}$, the $\boldsymbol{i^{th}}$ modal voltage collapses because any change in that model reactive power causes infinite change in the modal voltage.
As $\Delta Q = J_R \, \Delta V$
$\mathbf{J_R}$ is the reduced Jacobian matrix of the system.
we may write
The matrix $\boldsymbol{J_R^{-1}}$ is the reduced *V-Q* Jacobian.
Its $\boldsymbol{i^{th}}$ diagonal element is the *V-Q* sensitivity at bus ***i.***
As;

- Eigen values > 0, i.e. system is stable;
- Eigen values < = 0, ie. System is unstable.

For both cases, Eigen values has been calculated and their values are shown below in table 2. Before adding mobile units Eigen values indicate that the system voltage likely unstable=0.1456.

Aftre adding the mobile units an improvement in values of Eigen values may be noticed =0.9636, which means that the network has become more stable.

Table 2 . Eigen Values at both cases

Before mobile units		After mobile units	
Num	Eigen value	Num	Eigen value
	Mvar / %		Mvar / %
1	0.1465	1	0.9636
2	0.1465	2	0.9636
3	0.1465	3	0.9765
4	0.1465	4	2.6805
5	0.9929	5	3.1069
6	2.8837	6	4.157
7	3.5011	7	5.0292
8	3.5011	8	5.3309
9	3.5118	9	5.6049
10	3.5643	10	5.6439

III. Q-V curves

The *V-Q* sensitivity at a bus represents the slope of the *Q-V* curve at the given operating point. A positive *V-Q* sensitivity is indicative of stable operation; the smaller the sensitivity, the more stable the system. As stability decreases, the magnitude of the sensitivity increases, becoming infinite at the stability limit. Conversely, a negative *V-Q* sensitivity is indicative of unstable operation. A small negative sensitivity represents a very unstable operation.

Q-V curves for few busbars that are more sensitive to the change in reactive power (in Southern region and far from main generation) are shown below in figure 6 before and in figure 7 after adding the mobile units.

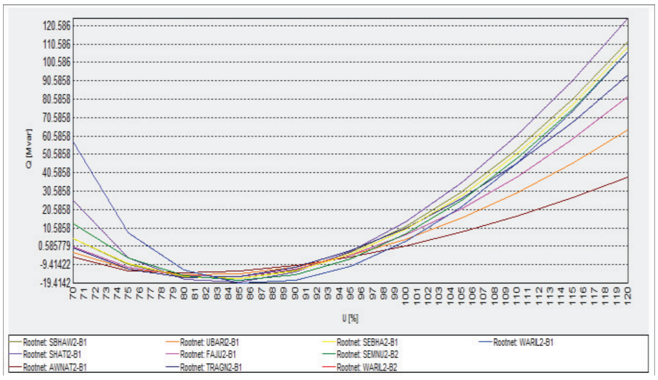

Fig. 6. Q-V curves without mobile units.

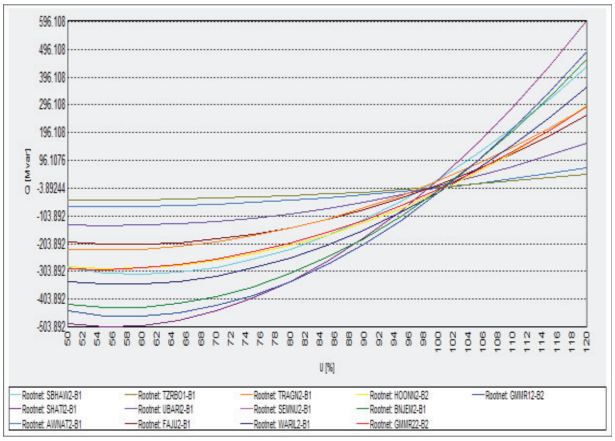

Fig.7. Q-V curves after adding the mobile units.

Increase in the margin of reactive power after enhance the network mobile units, where was the -14Mvar in the substation Await then became -70Mvar which means an increase in the margin of reactive power before voltage collapse.

IV. P-V curves

The P-V curves are produced by running a series of load flow cases. P-V curves relate bus voltage to load within a specified region and provide an indication of proximity to voltage collapse throughout a range of load levels.

Next figures illustrated P-V farthest generation area and more sensitive change reactive power for zone south, buses (AWNAT2, UBARI2, TZRBO1, FAJIJ2 and TRAGN2).

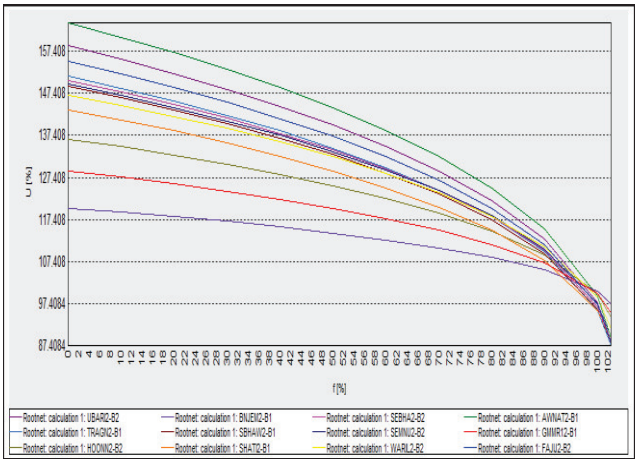

Fig. 8. P-V curves for buses at Southern zone before adding mobile unites.

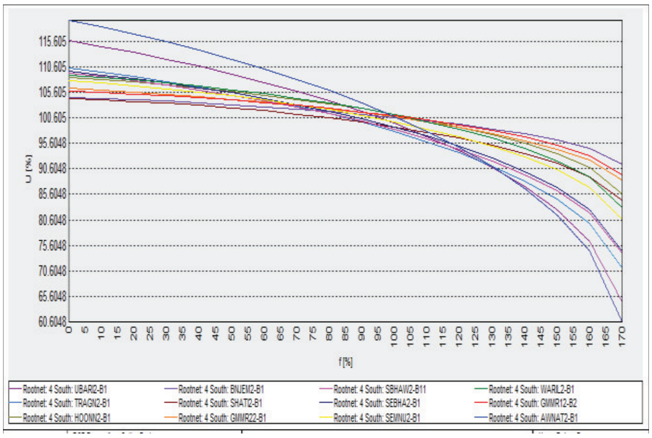

Fig. 9. P-V curves for buses at Southern zone after adding mobile unites.

Maximum transfer power before voltage collapse point for south region approximately at P=588 MW and after enhance network of mobile units became max transfer power in the southern region=850MW.

CONCLUSIONS

As the Libyan network since end of 2011 has not being strengthen with new generation stations a shortage of generation was expected and voltage instability was inevitable. Thus to avoid system collapses a number of mobile units were proposed to be planted over different places in Libya. The paper is a summary of study conducted to inspect the effect of planting these mobile units.
To realize the size of improvement that achieved the paper compare the results obtained before and after adding the mobile units. The figures show a great deal improvement with the scenario covered by the study and briefly explained in the paper. It is important to connect each group of mobiles in the right place to maximize the benefits. Set of conclusions are summarized in the following points:

- The Mobil units planted in the south region have improved the voltage stability of the network.
- The busbars at Southern region are generally more sensitive to change in reactive power from other busbars at other regions.
- After adding the mobile unites the most sensitive busbars still at Southern region (Awant-2, ubari-2 and turbo-1) but the degree of sensitivity becomes less.
- Eigen values calculated and their values indicated the system voltage likely unstable=0.1456, but we have noticed improvement in value Eigen values, which means that the network has become more stable=0.9661.

- Maximum power that can be transfered before voltage collapses is 588 MW for Southern region; and it is 1694 MW for central zone of Western region.
- After network enhancement the maximum power can be transferred becomes 850 MW for Southern region.

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