Voltage Profile Power Quality Effects In Radial Distribution Feeder Medium Voltage 33kilovolt And Remedial Measures

Mohammad A. Kanan, Abdulrahman S. Al-Gahtani, Mohammed Alqarni, Ramiz Assaf

Abstract: Poor Power Quality is seriously problematic for residential, commercial, agricultural, and consumers. During this study, analysis of poor power quality in rural distribution system during load flow in radial distribution feeder 33KiloVolt, Al-Urfan substation 132KiloVolt, Tareeb area is presented. The purpose of this study is to enhance the power quality of radial distribution feeder in Tareeb area by analyzing quantitative type of data of feeder; possible consumption solutions and create income statement to calculate net income statement, payback period and benefit to cost ratio to find out the optimum and economic result of solutions. This study shows the practical analysis of different cases of radial distribution feeder, which has important loads with high power quality disturbances. Through the study, analysis of voltage drop and power loss is calculated during simulation. Also, recommendations for optimization solution by using voltage regulator, capacitor bank to reduce these abnormalities and cost of poor power quality have been discussed. The distribution feeder has been drawn as built in order to simulation and analysis using CYMEDIS RAM software.

Index Terms: Power Quality, Voltage drop, Power Losses, Voltage Regulator, Capacitor Bank, CYMEDIS, Distribution System.

1 INTRODUCTION

Each distribution power system has its essential loss regardless of its superiority in countries of the world. The level of distribution loss is always greater than the transmission loss because of high level of current flowing through the system on low voltage level as compared with transmission network. Utility power system suppliers are duty obligatory guarantee that the subscribers are constantly supplied with the standard allowable limit of voltage. However, in some areas the subscribers at tail end of the electricity feeders may experience voltage drop due to various reasons such as Tareeb area is in the north side of Asir region in southern region of Saudi Arabia. It is rural area, difficult terrain. It one transmission substation that is Al-Urfan S/S (132/33KV), seven feeders outgoing, overhead lines which serve about 20,000 consumers to cover the area of Tareeb and its environs. It was receiving a lot of complaints by the consumers of residential and agricultural, particularly residing at the tail end of rural distribution feeder 33kv regarding low voltage. Some industrial units were also facing acute problems in maintaining voltage within permissible limits ±5% of nominal voltage 220V/380V, necessary for the smooth operation of machinery. The purpose of this study is to enhance the power quality of radial distribution feeder in Tareeb area by analyzing quantitative type of data of feeder; possible consumption solutions and create income statement to calculate net income statement, payback period and benefit to cost ratio to find out the optimum and economic result of solutions.

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A. Power Quality

Vujosevic, L. et al [1] presented a paper that evident form the study of various articles and published papers that voltage drop level is considered an important indicator to measure the power quality of the distribution system. Moreover, it has a significant impact to ensure the normal working of electrical appliances and their durability. Nunoo et al [2] presented a paper analyzing the causes and effects of voltage drop on the 11KV GMC sub-transmission feeder in Tarkwa, Ghana. Studies showed that the voltage drop, total impedance, percentage efficiency and percentage regulation on the feeder are 944V, 4.56Ω, 91.79% and 8.94% respectively. From the result, it is also realized that the causes of voltage drop on the feeder was mainly due to high impedance level as compared to the permissible value and this high impedance is caused by:-

(i) Poor jointing and terminations.
(ii) Use of undersized conductors.
(iii) Use of different types of conductor materials
(iv) Hot Spots etc.

C. Capacitor Bank Placement

Mohsin et al [3] presented Which led it attempts to find an optimal location and size required to install the capacitor by using genetic algorithm, through that, the contributed results in reducing the losses were obtained. David & David [4] presented the analysis of power system model for the imbalance of voltages to achieve at the optimum economical solution. Ahbab et al [5] focused on the reactive power compensation on medium voltage level radial distribution network by using step optimization of multi-step capacitor placement to achieve power losses using cuckoo search algorithm. Tulsky, et al [6] presented the analysis to improve power quality in radial distribution system by using suitable and size of capacitor banks placement. The study showed the suggestion of proper solution to reduce power losses. Chawla[7] presented similar method and analysis of Tulsky, et al [6]. But Liu et al [8] developed solution by using a reactive power compensation method by static var compensator and active filter.

D. Voltage Regulator Installation

Manikandan et al [9] proposed the method of discrete particle optimization for Voltage Regulator placement. This work focused on achieving optimal voltage control with voltage regulators and then to decrease the total cost and losses in radial distribution system. Moreover, Efkarpidis, [10], proposed method for Voltage control developments and later Efkarpidis [11] developed schemes based upon centralized voltage regulation to investigate the optimal placement and sizing of in line voltage regulators. Beleiu, et al [12] proposed a method for estimating the economic consequences of poor power quality with priority for the disturbance with significant economic effects.

2 METHODOLGY

The objective of quantitative methodology for this section is data collection, analysis and simulation by CYMEDIS, comparison of various compensatory solutions for voltage drop, calculate cost saving resulting from compensation power loss for one of the worst feeder from overall outgoing seven (7) feeders emanating from Al-Urfan substation in order to improve the power quality to end users (consumers) and network operators. Furthermore, the objective is to achieve permissible limits i.e. ±5% of a nominal voltage level 33KV of SEC standard. Hence, the study focused on total outgoing seven feeders from Al-Urfan substation that serve the geographical territory of Tareeb. MV Feeders are usually subjected to study on the basis of four salient/primary factors: Nature of loads; Length of feeder; Number of consumers; Power factor (P.f). These parameters are the major cause of poor quality for services provided to the consumers. Resultantly, the outcome will be helpful to achieve high power quality indices for Al-Urfan substation. Scope of work tree shown in Fig. 1.To achieve the goal mentioned above, the study will calculate the cost of technical energy losses of AL-Urfan substation. Additionally, the possible compensation solutions will be investigated and simulated using CYMEDIS software to select the optimal solution for worst feeder to enhance the substation performance.

3. NETWORK MODELLING AND ANALYSIS

AL-Urfan substation is 132/33KV and it consists of characteristics for two incoming feeders, seven outgoing feeders and two axillary feeders as shown in Figure. 2. The first step is to analyze the data of the seven feeders based on four factors which are; loads, power factor (P.F),

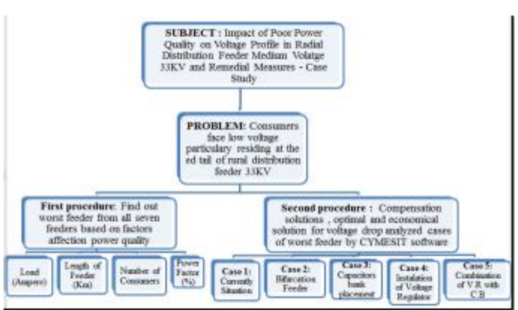

Fig. 1.*Scope of work*

feeder's length per kilometer (Km), and number of consumers to identify the worst feeder. Finally, cost will be analyzed of energy losses in different steps; Al-Urfan substation first step and after extract worst feeder in section of result/ discussion will be second step. Based on observation of feeders' data, analysis and comparison with Saudi electricity company standards (DPS) by designing/planning in distribution feeder 33KV. It depicts there is deviation of all feeders of expectation with different percentage which are caused poor power quality at consumers. The feeder B402 (highlighted) in Fig. 2 is the worst performing feeder among the other feeders owing to its quantum of supply and technical characteristics.

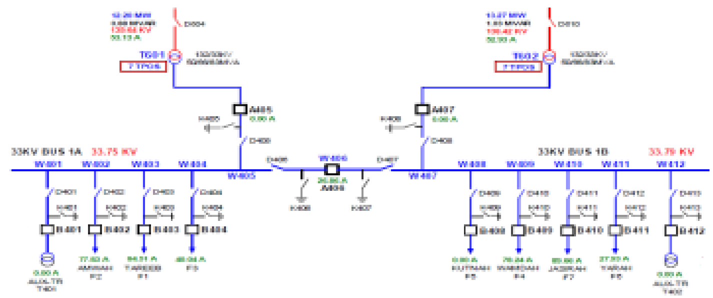

Fig. 2*.Worst Feeder B402, Al-Urfan Substation*

In order to analyze the feeder, different data is collected from various sources such as the single-line diagram of feeder B402, Al-Urfan S/S schematic diagram for 33KV bus, feeder loading, type and size of conductor, power factor etc. to draw the network that is available in Fig. 3, and hereby re-drawn in Fig. 4 by CYMEDIST software, version 8.0, 2017.

Fig. 3. *The single-line diagram of Feeder B402, with 169 Nodes*

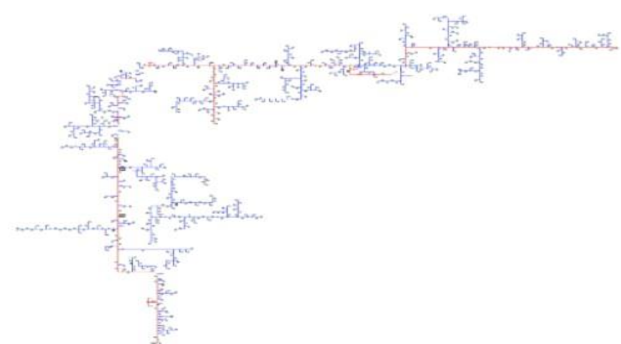

Fig. 4*. Re-drawn of Feeder B402 by CYMEDIST Software, with 169 Nods*

i. Case 1 Currently Situation at Peak Load

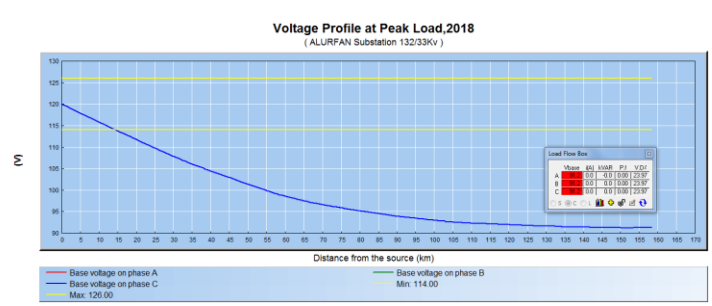

Fig. 5*. Voltage Profile at Peak load at Current Situation*

ii. Case 2 Study for the Bifurcation (Transfer Load)

It is not possible to transfer the load of this feeder to other feeder because it is radial in nature, and no other network is in close proximity to the feeder. Therefore, this option cannot be helpful to resolve the issue

iii. Case 3 Two Capacitor Banks Placement

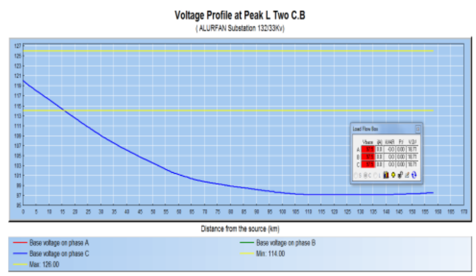

Fig. 6. *Voltage Profile at Peak load with Two Capacitor Banks*

iv. Case 4 Two Voltage Regulators Installation

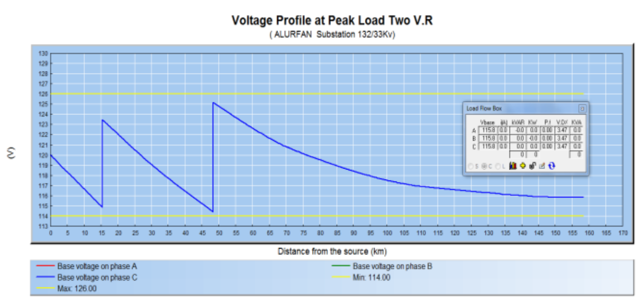

Fig. 7. *Voltage Profile at Peak load with Two Voltage Regulators*

v. Case 5 Combination of Voltage Regulator and Two Capacitor Banks

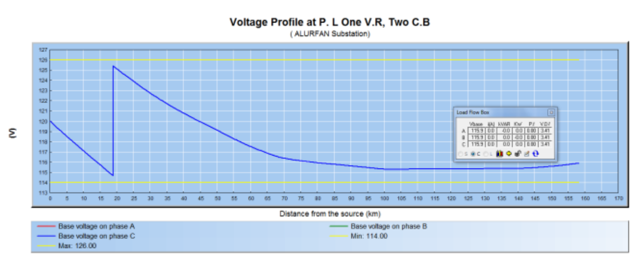

Fig. 8. *Voltage Profile at Peak load with Combination of Voltage Regulators and Two Capacitor Bank s*

TABLE 1: *Result of Load Flow of Compensation Cases*

Compensation Cases	*Result of Load Flow of Feeder B402*		
	Voltage drop%	*Losses (MW-h/year)*	*Cost of technical losses SR thousand/year*
Case 1: Current situation at peak load	*23.97*	*9760.442*	*1,952.09*
Case 2: Study for the Bifurcation (Transfer Load)	-	-	-
Case3:Two Capacitor Banks Placement	*18.71*	*8021.11*	*1,604.22*
Case 4: Two voltage regulators installation	*3.47*	*7524.17*	*1,495.43*
Case 5: Combination of Voltage regulator and Capacitor bank	*3.41*	*6031.574*	*1,206.31*

4 RESULTS AND DISCUSSION

According to data shown in TABLE 1, case 4, 5 solves the voltage drop issue and achieves permissible limits ±5% of nominal voltage as shown in Fig. 7, 8. In this case business profitability, financial statement and economy solution have been taken into consideration to find out the best possible solution. Hence, visible solutions have been studied which solve the issue in case 4 (Two voltage regulator), case 5 (One voltage regulator, Two capacitors bank) during predicting peak load until year, 2026 as shown in Fig. 9. However, the project cash flows, cost estimation, and maximum period of solution have been considered as shown in TABLE 2 to choose the optimal, economical solution for this study assuming the load growth at a rate of 2% annually.

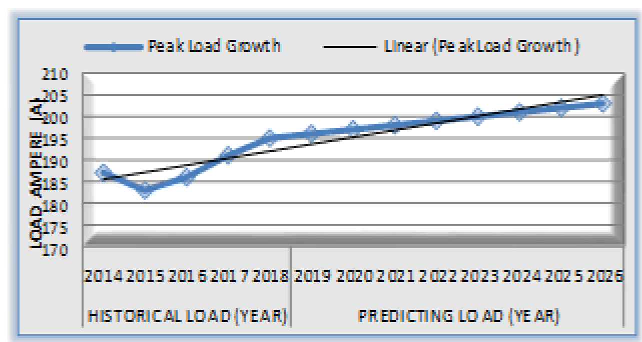

Fig. 9.*Historical and Predicting Peak Load 2014-2026*

The economic results of Table 2 shows that case 5 is preferred over case 4 based on the cost estimations. The comparison was based on multiple economic merits including the total net income (assuming no interest applied). The second method was by evaluating the annual worth considering that the two projects have different durations and annual worth is much preferred over present worth, the comparison applied an interest rate of 5% suitable for governmental projects. (Blank & Tarquin, 2005).

TABLE 2 *Project Cash Flow Table, IRR, Annual worth, Payback period for Cases 4, 5*

Profit/Loss Statement	Net Income (SAR)	
	Case 4	Case 5
2018	(954,008)	(557,293)
2019	572,497	659,196
2020	550,227	588,550
2021	527,568	524,764
2022	443,785	442,860
2023	379,267	380,296
2024	351,317	600,351
2025	329,401	
2026	760,739	

Total Net Income (no interest)	2,960,079.3	2,638,724
Annual Worth (i=5%)	343,398	427,126
Payback Period	Between year 2020,2021	Between year 2019,2020
Internal Rate of Return	54%	106%

5 CONCLUSIONS

Power Loss and Voltage drop are two concern in Tareeb power system that have been analyzed in AL-Urfan substation, feeder B402, 33Kv MV level by CYMEDIST software. The results of works conducted in this study show that the poor conditions of distribution causes low voltage quality and higher power loss. From the results of the feeder simulation by CMIDIST and subsequent analysis based on income statement, payback period, internal rate of return and benefit to cost ratio, it is concluded that optimal, practical, pragmatic and economical solution is case 5 install combination of one voltage regulator close delta with regulation ±15% and two capacitor banks 900 KVAR (300 KVAR per phase) Fixed at appropriate location, will lower power loss, solve issue of voltage drop by achieving (3.41% Voltage drop) with permissible limited ±5% of nominal voltage at peak load, increasing power factor to become 0.94, and improve power quality to consumers. The optimal solution selected will generate a net profit of 3.19 million Saudi Riyal (SAR) to the company and improve the satisfaction level of subscribers. The solution will be applicable and compatible with the network for the next six year up till 2024 and a reconsideration of the study will be required for the next period.

6. FUTURE WORK

Due to improve life style and more usage of digital electronic devices, the demand, for high quality power, has an increasing rate in the Tareeb area. Hence, not only power loss and voltage drop at the medium voltage level have been major problems but also harmonics, short circuits, voltage sags, and outages are other crucial concerns for the Tareeb power distributions system; because digital electronic devices need high quality power. On the other hand, they are causing more harmonics in the network. Besides theses disturbance factors, serious attentions must be paid to power loss and voltage drop at low voltage (LV) level in the Tareeb power distribution system. In the reason that present power distribution system has high power loss and voltage drop because of long length of feeder. Taking the above considerations into account, for the future – short circuits, harmonics, voltage sags, and other disturbance factors to the power quality must be analyzed to achieve an optimum case for the Tareeb power distribution system to meet the demand for high quality power. In order for power loss and voltage drop optimization at low voltage level, the performance of pole mount smaller size distributions transformer system versus pad mount distribution transformer system should be studied. Besides pole mount transformers system. Although the analysis could be conducted by means of different software; CYMDIST could be a better option for this purpose because it has variety of features for the distribution system simulation. CYMDIST has been designed for distribution systems simulation purposes. Ultimately, to satisfy the demand for high quality power, the performance of the Tareeb power distribution system must be enhanced. Yet, to achieve this goal, power quality disturbances such as harmonics, voltage sags, and outages must be studied and analyzed and optimum case must be acquired. Also for power loss and voltage drop minimization, the low voltage system with small size pole-mount transformers must be evaluated. Besides the disturbance factors optimization and power loss and voltage drop minimization, precise economic analyzes will be required in order to have an advantageous power distribution system. Finally, this study will be helpful for the management and staff as a reference to apply for the betterment and up gradation of their distribution system network.

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