Barriers and benefits of implementing a power quality program: Case Study Libyan distribution networks

Saad S. Sultan, Mohamed K. Darwish

Abstract— The purpose of this paper is to explore the obstructions faced by Libyan distribution networks in implementing a power quality program (PQP). It is also to state the benefits, which would accrue by implementing a PQP, which would make a major impact on Libyan distribution networks (LDNs), and which could be applied and adapted internationally. In order to achieve these objectives, an extensive literature review was conducted to understand the barriers and benefits of implementing a PQP, followed by a power quality survey questionnaire and interviews. Data were collected from LDNs, both from departments and individual staff members. Both SPSS 15.1 and Nvivo 9 were used in performing the analysis. The results revealed that no power quality program exists. Out of 16 barriers, 12 were statistically significant different since the P value <.05), which indicated that Libya distribution systems have already surmounted a few of the barriers to implementing a PQP effectively. The overall benefits of PQP implementation, which would have a positive impact on LDNs, are 11 benefits. Improving power quality disturbances (PQDs) and achieving the objectives of the implementation of PQP are, influenced by the distribution networks in tackle the obstacles, which remain. The findings of a LDN survey were compared with other studies and suggestions were made for the future improvement.

Index Terms— Barriers, Benefits, Libyan Distribution Networks, PQP Framework

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1 INTRODUCTION

Power quality programs have become some of the most recent services among distribution companies, both for private and state suppliers [1], [2]. For any distribution system to satisfy its consumers, the utility must keep improving power quality in a way, which that accommodates the increased demand for electricity [3], [4]. This requires the PQP to be implemented to start tackling the difficulties faced the distribution utilities in sustaining a high standard of power quality. A PQP can help in reducing the huge number of complaints from end users, and the costs represented in the damage to their equipment [5]. It can also have a positive impact on the electrical distribution companies, improving their service and saving some of the significant resources spent. Therefore, the distribution companies need to implement a PQ investigation program despite all the previous facts indicating an increase in PQDs, in the last two decades in particular [6].

Without establishing a clear vision of these barriers, such as the lack of the following: a clear strategy, customer awareness, accommodating economic growth, equipments standards, network design, resources, staff awareness, top management responsibility and power quality standards, together with an excessive increase of electronic equipments, then any efforts to improve power quality will be wasted in both time and resources. Accordingly, several less developed countries have compelled their utilities to implement PQPs, which are offered as a mandatory service, in response to the high increase in customer complaints [7], [8]. This is caused by the increase in sophisticated industrial and commercial equipments, while customers do not demand PQ standards to run it [9].

LDNs are among those systems facing poor power quality in under-developed countries. Unfortunately, statistical data show that in the last two decades, LDNs have not implemented power quality program [10], [11]. This is mainly because there is no power quality department established yet, to influence the measurement of PQDs. This absence of a power quality department is due to lack of awareness on the part of top management regarding the importance of power quality. As a result, LDNs have faced very significant difficulties in implementing PQP. In addition, lack of power quality awareness has led LDNs to face twelve significant difficulties through not implementing PQP [12], [13].

2 POWER QUALITY PROGRAMS (PQPS)

PQPs are particularly successful in developed countries rather than developing countries, due to the rapid adoption of sophisticated technology, as well as the higher level of PQ awareness among most of the end users, who recognize its importance. Furthermore, power suppliers in developed regions are trying to establish a high level of PQ standards in a short time, due to pressure from large industrial customers, as the use of sophisticated equipment increases [6].

In contrast, utilities in less developed countries are being pushed by the introduction of new technology from developed countries to improve and address their PQ issues. In response, some distribution companies have contracted a third party to solve PQ issues for their end users satisfaction; this is due to the inability of their engineers and technicians, who lack the skills and experience to solve these problems [2]. Therefore, government-controlled utilities are detached from the situation with regard to PQ issues. The failure to implement PQPs by some distribution utilities in developing countries have resulted in their supplying free power to their customers.

The distribution utilities in less developed countries are not worried about the quality of the power they provide to their clients. They believe that PQ has matured to the point, where it will not be of any importance in the future; moreover, their customers want only to be supplied with electricity, and are not concerned over quality [14]. Therefore, managers from distribution companies have concluded that some international electricity companies view implementing PQP as a business, rather than concerning themselves with issues of power distribution systems [2]. As a result, table 1 states the cost of industries and end users suffer losses due to poor power quality and the failure of implementing PQP.

TABLE 1

COST OF INDUSTRIES AND END USERS LOSSES DUE TO POOR POWER QUALITY

Country	PQ Disturbances	Total Cost annually	Aut hors	Methodology
Brazil	Harmonics Voltage sag, Power interruption	$ 1.2 m	[15]	Case study
Italy	Voltage sag	$ 235m	[16]	Case study
New York	Voltage sags	$ 1 m	[17]	Case study
China	Power interruption	$ 1.5 m	[18]	Presentation
Germany	Voltage sag, Power interruption	€32 bn	[19]	Panel Discussion
8 Developed Countries Austria, France, Italy, Poland, Portugal, Slovenia, Spain and UK	Voltage dips, Short interruptions, Long interruptions, Harmonics, Transients, and surges	€150 bn	[20]	Interviews and Questionnaire
Massachusetts USA	Voltage fluctuations, Voltage sag	$ 1.4 bn	[21]	Case study, Interviews
USA	Voltage dips, Short interruptions	$ 119 to $ 188 bn	[22]	Survey
Taiwan	Voltage dip	€ 1.7 m	[23]	Case study
Singapore	Short interruption, Voltage dip	€ 3 m	[24]	Survey
Sweden	Voltage dip	€ 2.4 m	[25]	Survey
California industries sectors	Harmonic, Voltage sag	$ 18.8 bn	[26]	Survey
France	Harmonic, Power interruption, Voltage dips	€1 m	[27]	Survey
UK	Transients, Interruption	£ 200 m	[28]	Insurance Compensation

To classify the barriers facing the implementation of a PQP and also the expected benefits from implementing such a program, a literature review has been carried out and is summarized in two sections, namely PQP barriers and PQP benefits:

3 BARRIERS TO IMPLEMENTING A PQP

Since 1980, PQ issues have been causing real and significant disturbances to the distribution systems and end users worldwide, becoming a global concern [29], [30], [31], [32], [33], [34], [35], [36]. Hence, the lack of awareness of PQ could result in utilities still suffering from PQ problems caused by end users' sensitive equipment for industrial, agriculture, residential and commercial [3]. Therefore, providing sufficient introduction, definitions and explanations for the most widespread PQ terms, will help in identifying the more common PQ disturbances that occur. Moreover, those producing or using the power, in particular in less developed countries, should understand what PQ means.

The reason is that as long as the concept of PQ is misunderstood by both the staff of the electrical distribution company and the end users, then the severity of PQ issues will increase every day, because the demand for power will increase and even double [1].

Several authors and researchers have determined different aspects of barriers according to their experience and their studies on the implementation of PQP.

A study in the UK revealed eight major categories of PQP barriers: lack of staff awareness regarding PQ issues; lack of enough resources; lack of PQ training courses; lack of top management committed to implementing good PQP; lack of long-term strategy for successful implementation; lack of end users' awareness; lack of PQ standards and lack of regular maintenance [37].

A study conducted by Ghatol and Kushare found two aspects of PQP barriers in less developed countries; lack of network designing; and lack of end users' awareness regarding power quality [38]. A survey in the USA, conducted for the North American Delivery Systems found two barriers to PQP implementation; lack of customer cooperation i.e. illegal connection made by end users; and lack of top management responsibility to face customer complaints [39]. A study in a Massachusetts distribution system found three barriers to PQP implementation; lack of PQ standards; lack of cooperation by end users; and lack of management commitment regarding end users' complaints [21].

A study by EPRI in the USA pointed out nine components of PQP implementation barriers; lack of top management commitment, support and encouragement; lack of skills, knowledge and experience among engineers' and technicians; lack of proper teams to analyse PQ disturbances; lack of training courses; and lack of a PQ database [40]. Another study in the USA, Asia, Africa, Australia, South America and Europe revealed a lack of power quality awareness among end users; and lack of PQ training courses [2]. A further study in the USA revealed two barriers believed to hinder the successful implementation of PQP; lack of a utilities distribution structure; and lack of suitable management structure and operation [34].

A study in Malaysia found that five barriers to implementing a PQP were a ; lack of education programs; lack of PQ awareness and guidelines; lack of training courses and support; lack of continuing research and development; and lack of financial incentives to encourage the staff to resolve PQ issues [8].

A survey conducted in 8 developed European countries, namely; Austria, France, Italy, Poland, Portugal, Slovenia, Spain and the UK; found that a lack of end users' awareness; lack of employee awareness and skills; lack of management commitment; and lack of PQ measurements and maintenance are the main barriers to PQP implementation. These factors have led to huge economic losses in Europe, exceeding €150bn annually [20]. Another survey in Europe found that the main difficulties encountered during the implementation of PQP are lack of PQ awareness among top management, engineers and end users; lack of network designing, due to increased power demand; lack of PQ standards; lack of PQ measurement [27].

A study in Canada revealed that three main factors impede the wider spread of PQPs; lack of PQ consultants; lack of PQ standards; and lack of PQ awareness on the part of end users [31].

A study in the Netherlands found five significant difficulties in implementing PQP, namely; lack of a distribution networks infrastructure; failure to handle end users' complaints so as to identify the underlying problems; lack of PQ contracts between suppliers and end users; increasing sensitive electronic equipments; lack of PQ training courses to raise the education and awareness levels of engineers to understand consumers' complaints better [41].

Another study in Germany found twelve barriers to PQP implementation; lack of distribution network designing, structure and size; lack of data on end users' load characteristics and structure; inadequate background and experience among employees regarding PQ; lack of PQ standards; lack of PQ measurement; lack of management planning and strategy [39].

A study in India found two major barriers to PQP implementation; lack of PQ measurement; lack of PQ awareness and skills among employees [42]. A second study in India found four significant categories of PQP barriers; lack of planning and designing the distribution network; lack of proper PQ teams; lack of PQ monitoring and databases to analyze customer complaints; and lack of PQ standards [43]. In Pakistan, a study found that lack of understanding PQ disturbances is a major obstacle to the implementation of a PQP to be achieved [44].

A study conducted by Moncrief, Dougherty, Richardson, and Craven found five main barriers to PQP implementation; lack of end users' awareness; lack of PQ equipment standards; lack of PQ awareness among employees; lack of PQ monitoring and databases regarding end users' complaints as a form of assistance to the utilities; lack of PQ measurements [45]. A study in Latin America found three barriers encountered during the implementation of PQP; lack of PQ monitoring and datasets; lack of PQ standards; lack of PQ employee' awareness and experience [46].

A study in Brazil found seven factors as the main barriers to PQP implementation; lack of distribution networks infrastructure; lack of studies and research; lack of distribution network design; lack of management planning; lack of technician and engineer skills and experience; lack of end users' awareness; lack of a clear strategy [47]. Table 2 shows the different and similar barriers by the above researchers.

TABLE 2

THE DIFFERENT AND SIMILAR OF POWER QUALITY PROGRAM DISCERNED BY THE ABOVE RESEARCHERS

Barriers	Country
lack of staff awareness, skills and experience	USA, European, India, Latin America, Brazil, Germany, Pakistan, Austria, France, Italy, Poland, Portugal, Slovenia, Spain and UK,
lack of enough resources	USA, UK
lack of top management commitment	USA, Massachusetts, Austria, France, Italy, Poland, Portugal, Slovenia, Spain and UK,
lack of long-term strategy and planning	USA, Brazil, Germany, UK
lack of end users awareness	USA, Asia, Africa, Australia, South America and Europe, Canada, Brazil, Austria, France, Italy, Poland, Portugal, Slovenia, Spain and UK,
lack of network designing	USA, European, India, Brazil, Germany
lack of training courses, and support	Malaysia, USA, Asia, Africa, Australia, South America and Europe, Netherlands, UK
lack of conducting research and studies	Malaysia, Brazil
lack of financial incentives	Malaysia

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lack of customer cooperation	USA, Massachusetts
lack of top management responsibility	USA, Netherlands
lack of PQ standards	Massachusetts , European, Canada, India, Latin America, Germany, UK
lack of PQ measurement	India, USA, Germany, Austria, France, Italy, Poland, Portugal, Slovenia, Spain, UK,
lack of PQ consultants	Canada, India, USA
lack of DNs infrastructure	Netherlands, Brazil
lack of PQ monitoring and database	India, USA, Latin America
lack of regular maintenance	UK, Austria, France, Italy, Poland, Portugal, Slovenia, Spain

4 Benefits of Implementing PQP

Power quality program, if effectively implemented, will lead to substantial benefits. Tackling the barriers, to a high level of PQ and high level of end users' satisfaction, requires both patience and discipline by the top management and the staff of distribution utilities to admit their level of knowledge in the past regarding power quality issues, and what the existing problems are they still face. This would help them to learn better how to avoid these obstacles, by raising their awareness of power quality [7].

A study conducted by Milanovic and Negnevitsky in Croatia stressed that the expected benefits of PQP implementation would make significant contributions to customer satisfaction [48]. They suggested that this level of customer satisfaction could be used as part of the process to identify the level of PQ issues, and where improvements could be made to increase this satisfaction. Barnard and Van Voorhis found that the main benefits of PQP implementation are increasing end users' awareness, increasing end users' satisfaction and improving power quality performance [2]. Labricciosa in his study in Canada stated that successful PQP implementation will result in reducing end users' complaints, and solving PQ disturbances [31].

A study by Aniruddh in the USA found that one of the main benefits of implementing PQP was to; provide PQ diagnosis systems and databases offering adequate data for end users to tackle PQ disturbances themselves, as their awareness level increased [38]. Janjic, Stajic and Radovic stated that when PQP was implemented successfully the distribution utilities gained the benefits of strategic planning by taking appropriate action, and making adequate preparations to introduce effective changes in the distribution systems regarding PQ; and satisfying their customers [49].

A study by Ronghua and Suan in Singapore found that end users' satisfaction and reducing PQ cost are the most valuable benefits of implementing PQP [24]. A study by Qureshi and Paracha in Pakistan found that the great benefits of PQP implementation are reducing the pressure of demand, improving network performance, increasing top management awareness, and developing the distribution systems for future requirements [36].

A survey by Salam and Nasri in Egypt found that one of the benefits of PQP implementation is to, increase customer satisfaction, raising the level of employee skills and awareness to tackle PQ issues [50].

A study by Gul in Turkey found that the most valuable benefits of implementing PQP are measuring PQ disturbances, increasing PQ training courses, providing enough knowledge, widening employees' experience and skills, educating end users and engineers and reducing the huge losses for end users and utilities [35].

The benefits of PQP revealed by the above researchers and studies can be summarized as: increasing end users' awareness and , satisfaction, improving power quality performance, reducing end users' complaints, monitoring and measuring PQ disturbances, providing PQ diagnosis systems and databases, providing strategic planning, reducing PQ cost, improving network performance, increasing top management awareness, raising the level of employee skills, experience, knowledge and awareness, increasing PQ training courses, and reducing the huge losses for end users and utilities.

In Libyan distribution networks, empirical research is required to categorize and underline the barriers and benefits of PQP in the context of a distribution utility, which has not implemented power quality programs in the last two decades. The knowledge and results obtained from this study will guide Libyan distribution networks implementing PQP, including all departments and staff, who are directly responsible for remedying power quality disturbances, in tackling any power quality problems by setting up clear and long-term strategies, with crucial objectives and serious barriers. Therefore, the implementation of power quality program requires great attention from the top management to help the distribution networks to achieve their goal of offering and providing a power quality program in practice [51].

5 Research Method and Survey Instrument

The above literature review helps the researcher to understand the different barriers to PQP implementation and the expected benefits of PQP. Next, a survey questionnaire and interviews were conducted in the Libyan distribution systems. The questionnaire was designed in two main parts and, followed by 44 face-to-face interviews.

5.1 Part A

Respondents were asked to define how far any of the 16 PQP potential barriers (BA) cause current difficulties in implementing power quality program in Libyan distribution systems. The 16 PQP barriers are listed in table 3. All factors were designed in a five-point Likert scale format (1=not applicable; 2= very low extent; 3= low extent; 4= moderate; 5= high extent).

TABLE 3

LIST OF POWER QUALITY PROGRAM BARRIERS

	PQP Barriers
BA1	lack of staff awareness, skills and experience
BA2	lack of end users awareness
BA3	lack of customer cooperation
BA4	lack of long-term strategy and planning
BA5	lack of top management commitment
BA6	lack of network designing
BA7	lack of distribution networks infrastructure
BA8	lack of conducting research and studies
BA9	lack of top management responsibility
BA10	lack of training courses, and support
BA11	lack of financial resources
BA12	lack of enough incentives
BA13	lack of PQ measurement
BA14	lack of PQ consultants
BA15	lack of PQ standards
BA16	lack of PQ monitoring and database

5.2 Part B

Respondents were asked to judge how far one of 11 PQP possible benefits (BN) would be achieved by implementing PQP within Libyan distribution systems. The 11 PQP expected benefits are listed in table 4. All factors were designed in five-point Likert scale format (1= not sure; 2=negative; 3= moderate; 4= positive; 5= very positive).

TABLE 4

LIST OF POWER QUALITY PROGRAM BENEFITS

	PQP Benefits
BN1	Increasing the end users awareness
BN2	Increasing the end users satisfaction
BN3	Improving PQ performance
BN4	Reducing the end users complaints
BN5	Monitor & Measuring PQ disturbances
BN6	providing PQ diagnosis system and database
BN7	Reducing the huge losses of PQ cost
BN8	Increasing the top management awareness
BN9	Increasing the employee skills and awareness
BN10	Increasing PQ training courses
BN11	Providing strategic planning

The questionnaire was sent to head managers, middle managers, engineers, technicians and employees, with total number of 540 copies and it conducted in April-June 2009. Of 540 copies, 441 copies were returned, of which 397 were appropriate for data analysis, giving a response rate of 81%. The data were analyzed by using Statistical Package for Social Science (SPSS) software, version 15.0.1.1.

In addition, 44 interviewees participated in this study to investigate why there were barriers to PQP implementation. The interviewees consisted of head managers, middle managers, engineers, technicians and employees from four departments, mainly those dealing directly with power quality issues. These were Planning, Training, Distribution, and Customer departments in LDNs. After the interviews conducted the data were transcribed and coded by using NVivo 9 [52], [53].

6 Results and Discussion

Data gathered by the questionnaire from the distribution system respondents were checked in terms of accuracy, outliers and, normality; then analyzed using (SPSS) software. Table 5 shows the type of distribution networks along with the categories of end users involved in the study. Large distribution networks were considered to have more categories of end users; the western distribution network (WDN1), southern-west distribution network (SWDN2) and eastern distribution network (EDN4); whereas small distribution networks had 1 to 2 categories of end users; the central distribution network (CDN3) and southern-east distribution network (SEDN5).

TABLE 5

TYPES OF DISTRIBUTION NETWORKS

Distribution Networks	Residential	Commercial	Industrial	Agricultural
WDN1	√	√	√	
SDN 2	√		√	√
CDN3	√	√		
EDN 4	√		√	√
SDN 5	√			√

The data were measured in order to evaluate the correlations between the barriers to PQP; therefore factor analysis was performed. The Kaiser-Meyer-Oklin (KMO) measure of sampling Adequacy value was 0.82, which exceeds the recommended value of 0.6 [54] and the Bartlett's Test of Sphericity was also highly significant (Chi-Square = 4847.51 with 561 degrees of freedom, at $p<0.001$), reaching statistical significance in the correlation matrix. This implies that the factor analysis of 16 factors of PQP barriers was appropriate and confirms that all the items were statistically significant, which are judged to be an excellent validation of factor analysis.

The reliability test of Cronbach's α for all factors in parts A and B of questionnaire is 0.82. Cronbach's α above the cited minimums of 0.70 [55] is considered to be high and acceptable alpha, giving an evidence that the total Cronbach's alpha was judged to be reliable for the questionnaire.

Table 6 summarizes the Varimax - rotated factor matrix, which accounted for about 64 % of the total variation. The correlation matrix disclosed the presence of many items <0.5 and items higher were considered to be important. Questions BA 1-4 belong to factor 1 and can be categorized under 'lack of awareness', whereas questions BA 5-9, belong to factor 2 and are categorized as 'lack of top management attention'. Questions BA 10-12 belong to factor 3 and pertain to 'lack of resources' and finally questions BA 13-16 belong to factor 4, dealing with 'lack of power quality involvement'.

6.1 Part A

Table 6 shows that in the ANOVA test, out of 16 barriers, 12 were statistically significant different at the P value <0.05. The significant barriers are BA1, lack of staff awareness, skills and experience, BA2, lack of end users awareness, BA4, lack of long-term strategy and planning, BA5, lack of top management commitment, BA6, lack of network designing, BA7, lack of distribution networks infrastructure, BA9, lack of top management responsibility, BA10 lack of training courses and support, BA11, lack of financial resources, BA13, lack of PQ measurement, BA14, lack of PQ consultants, BA15, lack of PQ standards, and BA16, lack of PQ monitoring and database.

TABLE 6

VARIMAX ROTATED FACTOR MATRIX

Items	Factor 1	Factor 2	Factor 3	Factor 4	Sig
BA1	0.797				0.035
BA2	0.731				0.033
BA3	0.699				0.337
BA4	0.666				0.036
BA5		0.801			0.044
BA6		0.754			0.049
BA7		0.676			0.021
BA8		0.641			0.447
BA9		0.623			0.043
BA10			0.837		0.022
BA11			0.787		0.044
BA12			0.755		0.242
BA13				0.766	0.031
BA14				0.711	0.041
BA15				0.701	0.029
BA16				0.671	0.128

In addition, a post hoc Least Significance Difference (LSD) test was carried for these twelve barriers. The test found that large distribution networks WDN1, SDN2 and EDN4 faced some particular barriers compared to other small distribution networks in LDNs. SDN2 faces three factors; F1, lack of awareness, F2, lack of top management attention, and F4, lack of PQ involvement, whereas WDN1 and EDN4 face F1, lack of awareness, F4, lack of PQ involvement and F3, lack of resources. As a result, it can be in referred that Libya's distribution systems have so far struggled to implement PQP effectively.

6.2 Part B

This part of the questionnaire shows the analysis of the mean level of PQP benefits within LDNs. The response scale of the survey was divided into three levels of outcome, where (1.51 to ≤ 250 was Negative, 2.51to ≤ 3.50, moderate and, 3.51to ≤ 5 Positive). Table 7 presents the overall results of PQP benefits, which would have a positive impact on increasing end users awareness, increasing their satisfaction, improving PQ performance, reducing end users' complaints, monitoring and measuring PQ disturbances, providing PQ diagnosis systems and databases, reducing the huge losses through PQ costs, increasing top management awareness, increasing the employees' skills and awareness, increasing PQ training courses and providing strategic planning in LDNs.

TABLE 7

BENEFITS OF SURVEY RESULTS

No	DN1	DN2	DN3	DN4	DN5	Overall
BN1	3.84	3.96	3.45	3.27	3.8	3.66
BN2	3.91	3.56	3.54	3.73	3.53	3.65
BN3	3.65	3.68	3.54	3.64	3.4	3.58
BN4	3.51	3.52	3.68	3.51	3.47	3.53
BN5	3.48	3.48	3.82	3.53	3.33	3.52
BN6	3.73	3.56	3.67	3.49	3.46	3.58
BN7	3.52	3.48	3.49	3.55	3.66	3.54
BN8	3.76	3.88	3.82	3.77	3.93	3.83
BN9	4.25	3.31	3.75	3.53	3.48	3.66
BN10	3.43	3.68	3.73	3.25	3.52	3.52
BN11	3.48	3.66	3.61	3.52	3.56	3.56

7 INTERVIEW RESULTS

Table 8 shows the twelve difficulties discussed in the interviews, which are similar to what were obtained from the questionnaire. These results indicate that LDNs have not implemented PQP. It showed that the top management has not paid enough attention, support, commitment and responsibility to setting up long-term strategies to implement PQP. Therefore, LDNs have lost LD 464 million annually due to poor power quality and the failure to implement PQP [56].

TABLE 8

BARRIERS TO POWER QUALITY PROGRAM IMPLEMENTATION FROM ANALYSIS OF THE INTERVIEWS

Barriers	Head Managers	Middle Managers	Engineers	Technicians
BA1	4.5%	69.85%	12.64%	13.01%
BA2	2.85%	56.26%	20.38%	20.51%
BA4	3.9%	60%	17.18%	18.92%
BA5	7.56%	56.68%	17.91%	17.84%
BA6	2.32%	71.44%	16.12%	10.12%
BA7	17.64%	50.1%	16.93%	15.33%
BA9	6.12%	76.75%	17.13%	0%
BA10	16.53%	44.35%	3.72%	35.4%
BA11	2.53%	58.26%	7.5%	31.71%
BA13	0%	95.27%	0%	4.73%
BA15	3.08%	83.28%	2.91%	10.73%
BA16	8.81%	64.18%	16.67%	10.34%

Moreover, most of members of staff involved in implementing PQDs are middle managers, 52.4% of who held of high diploma qualifications, which is considered the minimum educational level. This means that they are not highly knowledgeable and aware enough to cope with the current severe level of power quality as well; moreover, this level of education would not enable them to understand and participate in implementing PQP. Almost 38% of engineers and technicians have between 6 and15 years of experience, but lack awareness and skills. They should be better taught and trained before they can deal with PQP implementation.

8 Proposed PQP Framework

Multivariable Linear Regression (MVLR) was conducted to identify which factors have significant impact on PQP implementation [57]. An acceptable model was developed on the basis of these factors. It is clear that all these factors are significantly correlated, since all p values are less <0.05 and are substantially affected by the lack of awareness of the implementation of PQP in Libyan distribution networks as shown in Fig.1.

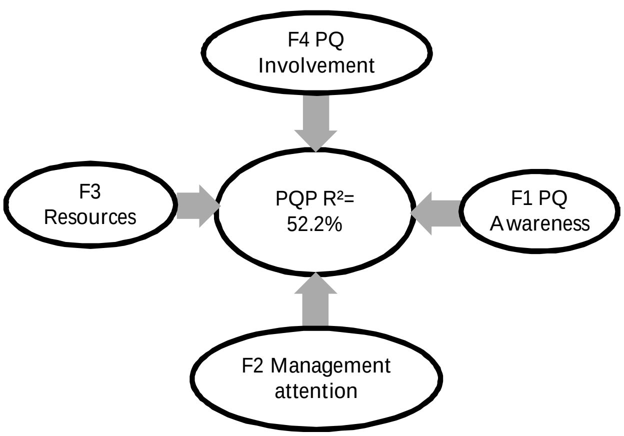

Fig. 1. Power Quality Program Model for LDNs

Table 9 shows the value of R^2 as 52.2% for this model, which indicates how much of the variability in the outcome is explained by the predictors. This also indicates that the validity of this model is very good. Consequently, this model can be accepted and applied for LDN to implement PQP, since all the predictors increase by one unit (see β value). It also indicates that the two factors most highly affected by lack of PQ awareness are F2 (β=34.5%) and F3 (β=31.6%). As a result, the regression analysis shows that the linear relationship between the outcomes, which is PQP, is explained by the model and predictor factors.

TABLE 9

REGRESSION RESULTS OF POWER QUALITY PROGRAM FACTORS

Scale	β	Std .Error	t	P	R^2	Cronbach's alpha
F1	0.202	0.031	4.538	<.001	0.522	0.811
F2	0.345	0.041	7.573	<.001		0.841
F3	0.316	0.029	8.097	<.001		0.806
F4	0.171	0.028	4.427	<.001		0.851

9 Conclusion

This study is the first to investigate the barriers and benefits of PQP within Libyan distribution systems. It contributes by providing an insight into the overall efforts needed to implement PQP implementation and the main reasons underlying its failure. It is also the first to explore the expected benefits, to be gained from implementing PQP. The findings will be applied to build a PQP framework guideline to be implemented in LDNs. Four main factors of PQP barriers were determined from this study, namely; lack of awareness (lack of staff awareness, skills and experience, lack of end users' awareness, lack of customer cooperation, lack of long-term strategy and planning); lack of top management attention (lack of top management commitment, lack of network designing, lack of infrastructure for distribution networks, lack of continuing research and study, lack of top management responsibility); lack of resources (lack of training courses and support, lack of financial resources, lack of enough incentives); lack of power quality involvement (lack of PQ measurement, lack of PQ consultants, lack of PQ standards, lack of PQ databases).

The large distribution networks WDN1, SDN2 and EDN4 faced some particular barriers, unlike the smaller distribution networks in LDNs. SDN2 faces three factors F1, lack of awareness, F2, lack of top management attention, and F4, lack of PQ involvement; whereas WDN1 and EDN4 face F1, lack of awareness, F4 lack of PQ involvement and F3 lack of resources. The result of this is that Libya's distribution systems have struggled so far to implement PQP effectively. In general, the finding shows that LDNs suffer the four factors of PQP barriers. These four factors appeared in USA, European, India, Malaysia, Latin America, Brazil, Germany, Pakistan, Austria, France, Italy, Poland, Portugal, Slovenia, Spain and UK.

The implementation of PQP plays a significant role in improving power quality issues. The purpose of implementing PQP is associated with completing and developing systems to achieve the strategy's objectives set by all departments. Therefore, this study reveals poor implementation of PQP in LDNs, because they are not moving from the suggested strategies to realistic performances. According to qualitative analysis, this gap will continue if PQP is not implemented. Therefore, one of the main challenges in implementing PQP is to link all the difficulties with both its objectives and strategies. Hence, the implementation difficulties should be regularly assessed to identify the hidden reasons associated and causing poor implementation. Thus, without adequate knowledge, awareness, planning, designing, preparation, training, power quality standards, clear strategy, and most important the support of top management for this program, power quality disturbances will never end and their severity will affect all consumers.

In response to this, a PQP for LDNs was found to have a positive impact on increasing end users' awareness, and satisfaction, improving PQ performance, reducing end users' complaints, monitoring and measuring PQ disturbances, providing a PQ diagnosis system and database, reducing the huge losses through PQ cost, increasing top management awareness, increasing employees' skills and awareness, increasing PQ training courses and providing strategic planning. They are needed because LDNs have not yet implemented PQP due to the failure to establish power quality departments.

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AUTHORS' INFORMATION

Saad S. Sultan has received his BSc degree in Communication from Ibn-AL Hytham High Centre for Technological Education and Scientific Research, Tripoli, Libya and the MSc degree in Electrical Engineering with Power Electronics from Bradford University, UK, in 2007. He has joint Brunel University in 2009 to carry out his PhD research in the area of Power Quality Issues. He is a student member of IET in Power Electronics System Network in field of Power Quality.

Mohamed K. Darwish (BSc, PhD, IEE Member 89–CEng 90, MIEEE). Dr Darwish has received the BSc degree in Electrical Engineering from Helwan University, Cairo, Egypt, and the PhD degree from Brunel University in 1978 and 1987 respectively. Dr Darwish is currently a Senior Lecturer in Power Electronics. He has over 20 years experience of research and teaching in the area of Power Electronics. His research interests include active filtering techniques, UPS systems and Power Quality issues. Dr. Darwish has published over 100 papers in leading journals and conferences.