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Practical Approach for Capacity Expansion of HV/MV Substations in Long Range Planning–The Case of Beirut Central District

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Abstract – The aim of this paper it to present a new practical approach for determining capacity expansion of High Voltage/Medium Voltage (HV/MV) substations deployed in distribution power systems of a district area that is undergoing a planning period spanning over 10 years. It estimates electrical loads over the spanning period based on actual full occupancy loads of installed Medium Voltage/Low Voltage (MV/LV) transformers. The aim was to estimate accurately the expansion capacity of the existing HV/MV substations. The approach was initiated by performing a detailed analysis to determine the standards followed by the power utility in supplying its existing customers in the district area with full occupancy installed MV/LV transformers which were based on the land use and built-up area. The calculated values were then utilized in estimating electrical loads of the overall district's planned buildings given the yearly expansion of the built-up area. Finally, sensitivity analysis has been applied to determine the best estimates of the calculated loads over the planning period which was used to accurately determine the expansion capacity of the existing HV/MV substations. The Beirut Central District, undergoing major expansion works for the period starting 2010 and ending in 2030, was taken as a case study. The outcome of this approach revealed that an expansion capacity for its HV/MV substation of only 105 MW was needed to meet the load demand by the end of the planning period *i.e.* by year 2030.

Keywords – diversity factor, HV/MV substations, power system operation, power system planning.

1. INTRODUCTION

One of the primary tasks of medium-term optimal planning period, spanning up to 10 years, of distribution power systems is to accurately estimate load requirements by the end of the set planning period. The outcomes of the load estimation task are normally used in infrastructure designs, planning, and operation of the power distribution system. For long-term planning period, that would span for a period over 10 years, another planning task shall be achieved which is the determination of the expansion capacity of existing HV/MV substations supplying the distribution power system.

Over the past few decades, a large number of mathematical models and algorithms have been developed for solving the long term load forecasting problems which are utilized in various studies such as expansion planning [1], tariff setting, capital investment, and others. Alfares and Nazeeruddin [2] have presented a survey of electric load forecasting techniques. Earlier comprehensive reviews have been conducted by Willis [3] and Moghram and Rahman [4]. The survey presented in [2] has classified load forecasting techniques into nine categories: multiple regression, exponential smoothing, iterative reweighted least squares, adaptive load forecasting, stochastic time series, ARAMAX models based on genetic algorithms, fuzzy logic, neural networks, and knowledge based expert systems. Hahn *et al*. [5] have presented an overview of various models and methods used to predict future load demands.

El Naggar and Al Rumaih [6] examined the performance of three estimation techniques used for long term peak load forecasting: genetic algorithms, least error squares, and least absolute value filtering. They observed that the genetic algorithms approach is the best among the three examined approaches for its robustness and suitability for parallel implementation.

Chui *et al*. [7] have forecasted the annual energy, peak load and base load demand up to the year 2025. They used autoregressive, simple linear and multiple linear regression models for long term forecasting of electricity demand. The resulting models using different forecasting techniques are compared through a number of statistical measures and the most accurate model was selected.

Sonika *et al*. [8] have studied long term load forecasting of two substations in two different cities in India using fuzzy logic methodology. They have used as input to their model population and load data for the years 1997-2014 in order to forecast the load for the years 2015-2023 in these two stations.

Tuunanen *et al*. [9] developed a novel long term forecasting process for electricity distribution business using two-stage forecasts. The first-stage forecast is a traditional long term forecast where volume and consumption forecasts are in a key role. The second-stage of the process takes into consideration the effects of the future technologies (energy efficiency, electric vehicles, energy storages, demand response and micro generation).

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Hong *et al*. [10] have presented an approach to the long term load forecast where they modernized predictive modeling, weather normalization, and probabilistic forecasting with multiple linear regression models and hourly information.

Accurate load estimation holds a great saving potential for long range planning of distribution systems. Haida and Muto [11] observed that forecasting errors would eventually result in substantial increases in the operating costs.

This paper presents a new and practical approach for accurately determining the expansion capacity of existing HV/MV distribution substations deployed in a district area that is undergoing long range planning period, spanning over 10 years. It estimates electrical loads based on actual full occupancy loads of existing MV/LV transformers, built-up area (BUA), and type of land use of existing buildings.

The new approach is applied to Beirut Central District (BCD), which falls into this category of long range planning period, spanning around 20 years, starting on 2010 and ending on 2030. Predicting accurate electrical loads for the overall BCD is a necessary step that has to be in line with the sole power utility of the country, Electricite du Liban (EDL), that recently adopted generation and transmission master plan for the next twenty years [12], and the national policy for the power sector adopted by the Government of Lebanon in 2010, [13]. This policy is a comprehensive plan aimed at developing the sector in generation, transmission and distribution, the supply/demand balance, and the legal framework of the sector. Great savings will be reflected on both the consumer as well as the utility sides for upgrading HV/MV substations of distribution power systems at the appropriate time.

2. METHODOLOGY OF THE APPROACH

The methodology of the new approach for determining capacity expansion of HV/MV substations deployed in distribution power systems is outlined in the following steps:

Step 1:

Initially, a detailed analysis was performed to determine the standards followed by the power utilities in supplying their existing customers in the district area, which has been undergoing the long range planning, in selected zones of constructed buildings, with full occupancy installed MV/LV transformers which were based on their buildings' types of land use and BUA. To perform this step efficiently, a comprehensive site survey was conducted on existing buildings of the district area as well as the designs of all planned buildings was reviewed.

To properly establish an excellent estimate of loads in the district area, the zones in the constructed area shall be classified according to their land use and luxury levels, as follows: Zone 1 for Office Buildings (OB), Zone 2 for Top Luxurious Residential Buildings (TLRB) and Zone 3 for Average Luxurious Residential Buildings (ALRB).

The BUA supplied by each MV/LV transformer in the three selected zones (OB, TLRB, and ALRB) shall be utilized to calculate the actual full occupancy (100 %) VA/m^2 on the transformer level and the value is reflected to the district area's HV/MV substation.

To prolong the lifetime of the transformers, the load on each MV/LV transformer was not to exceed 85% of its rated MVA value, this load usually corresponded to maximum-efficiency operation. The diversity factors for network levels which will be used in the calculations were assumed as follows: 0.77 for MV loops level and 0.87 for HV/MV substation level.

Step 2:

The calculated values of full occupancy installed loads, in VA/m^2, calculated in Step 1, were then be utilized in estimating electrical loads of the overall district area' planned buildings, over the spanning period, given the yearly additions of the BUA and type of land use of constructed buildings.

Step 3:

Finally, sensitivity analysis was conducted to determine the best estimates of calculated loads for the overall district area over the same period with the aim of accurately determining the expansion capacity of the existing district area' HV/MV substation.

The sensitivity analysis has been carried out to study the effects of sustainability and changes in land uses for various occupancy rates (current, full, and expected). The expected occupancy (average between current and full occupancy rates) was considered reasonable for the anticipated types of clients and luxury levels at the overall district area. Six scenarios were considered and these can be summarized as follows:

Scenario 1: Adopted the original data related to BUA and land use (normally 70 % residential and 30% office buildings) assuming that no sustainability measures were applied to those buildings where construction was not yet started.

Scenario 2: Ditto as Scenario 1 except 15% sustainability was achieved through several energy saving measures, thus reducing the VA/m^2 consumption to those buildings in the overall district area where construction is not yet started.

Scenario 3: Ditto as Scenario 1 except for the BUA of selected land usages which have been modified as elaborated below:

❖ BUA of land usages in the district area where construction was completed or under construction were not modified.

❖ BUA of land usages related to hotels, commercial buildings, and retails establishments were not modified yet.

❖ All other BUA of assigned land usages related to office and residential establishments where construction had not yet started was modified, as follows:

1. The BUA of assigned land usages related to residential were increased thus raising the percentage of residential buildings to 80%.
2. Similarly, the BUA of assigned land usages related to office buildings were decreased by the same amount thus reducing the percentage of office buildings to 20%.

Scenario 4: Ditto as Scenario 3, with 15% sustainability being applied, thus reducing the VA/m^2 consumption to those buildings in the overall district area where construction was not yet started.

Scenario 5: Ditto as Scenario 3 except for items 1 and 2 which become as follows:

1. The BUA of assigned land uses related to Residential were decreased, reducing the percentage of residential buildings to 60%.
2. Similarly, the BUA of assigned land usages related to Office were increased by the same amount, hence raising the percentage of office buildings to 40%.

Scenario 6: Ditto as Scenario 5, with 15% sustainability being applied, thus reducing the VA/m^2 consumption to those buildings in the overall district area where construction was not yet started.

An average load profile of the six scenarios for the full, current, and expected occupancy rates were used to determine the best estimate to expansion capacity of the HV/MV substation.

3. BACKGROUND ON BEIRUT CENTRAL DISTRICT

The BCD, which was totally demolished during the civil war years, is currently undergoing a huge reconstruction project, composed of several development projects of wide variety and scope, and this has made it rather difficult to estimate the demanded electrical load, especially during high seasons such as the hot summer days, and the touristic seasons. Furthermore, the luxury of the developments and the type of clients/owners promoted a concept that power consumption in most zones of the BUA will be very high compared to traditional loads normally connected to EDL.

According to the major reconstruction plan, the overall BCD consists of two districts: the traditional district BCD1, and Beirut's New Waterfront District BCD2. Located at the historical and geographical core of Beirut, the vibrant financial, commercial and administrative hub of the country, the old BCD1 has regained its attractiveness as the restoration of many of its buildings, infrastructure, and construction of many new buildings have been completed.

As an expansion of the reconstruction and development plan, a new project (BCD2) has been prepared, studied, and finalized. This district falls along the axes extending from the historic core of the BCD1 on one end, to the sea promenade on the other end; embodying a smooth extension to the existing BCD1 sectors. The planned themes and textures of the newly proposed public spaces in the selected zones (public squares, green parks, pathways, waterside walkways), as well as the high-value building blocks and new shopping streets, are meant to create new sub centers of activities in the New Waterfront District and enhance their overall value, and to provide new touristic attractions. The project accommodates for functions such as residential, offices, hotels, commercial, public, cultural, leisure, religious, parking and other multi-use utilities.

The proposed development in BCD2 zone is further divided into two sectors, sectors A and D, with total built up area of 1,611,562 m^2. Sector A includes the New Waterfront Promenade, the Beirut Marina (both already executed), the Park (some 80,000 m^2), and other open public spaces. As for Sector D, it consists of a high-density multi-purpose area to be developed; the north of the traditional city center, the eastern marina and extends till the first Basin of the seaport.

The total BUA of buildings in the overall BCD is 4,561,562 m^2, distributed as follows:

A) 2,950,000 m^2, of buildings in BCD1 of which a total of 1,239,774 m^2 is for buildings that are already completed, 361,058 m^2 for buildings are under construction, and 1,349,168 m^2 for buildings are not yet constructed; and

B) 1,611,562 m^2, of planned buildings in BCD2 which was initiated in 2013.

Construction of new buildings in part of BCD1 has started in 2010 and was completed in 2014. Construction of the remaining new buildings has started in 2013 and scheduled to be completed in 2018. On the other hand, construction of all new buildings in BCD2 was initiated in 2013 and scheduled to be completed in 2030.

4. STATUS OF THE EXISTING BCD'S HV/MV SUBSTATION

Figure 1 shows a schematic diagram for the existing BCD's HV/MV substation which has been in operation since February 2000.The substation consists of three 80 MVA, 220/20 KV transformers (denoted as TR1, TR2, and TR3), of a total power rating of 240 MVA which supply power to the existing buildings in BCD1 and to other areas located outside this district. It also contains two 40 MVA, 66/20 KV transformers (TR4 and TR5) which are used by EDL to energize two of its 66 KV substations.

For a proper and reliable operation, the peak load of the existing BCD substation shall not exceed 160 MVA, the rating of the two 80 MVA transformers, assuming one transformer is always on standby. This is why an HV/MV substation is always referred to by n+1 redundancy transformers.

Figure 1 provides the maximum measured peak loads supplied by the substation to areas located in/outside BCD. The peak loads measured at the MV breakers of the substation during summer 2010 are further elaborated as follows:

❖ Peak load measured at transformer TR1 is 45.4 MVA, of which about 19.7 MVA peak are supplied to areas outside the BCD through the following feeders:

1. 9.3 MVA to the American University of Beirut located in the vicinity of the BCD.

2. 6.2 MVA to the ABC Shopping Mall and the surrounding areas.

3. 4.2 MVA (JUPITER) supplies peak loads in the hotels region.

❖ Transformer TR2 is used to feed TR4 and TR5 (2x40 MVA 66/20 kV) transformers, backward at the MV bus bar levels, thus supplying 60 MVA to EDL's Gaz and Ain El Mreisseh 66 kV substations.

❖ Peak load measured at transformer TR3 is 34.6 MVA. It is used to supply about 4.7 MVA peak to loads outside BCD through the following feeders:

i. PORT CONTAINERS which supplies peak loads of about 4.3 MVA to Beirut Port.

ii. BASIL which supplies peak loads of about 0.42 MVA.

It is observed that the power delivered to BCD1 is 55.7 MVA as measured on BCD's HV/MV substation during peak of summer 2010.

Furthermore, it is observed that a load of about 24.4 MVA is being supplied by the substation to areas located outside BCD and another load of about 60 MVA is also supplied by the substation to feed EDL's Gaz and Ain El Mreisseh 66 kV substations.

Therefore, based on the concept of n+1 transformer redundancy, the available capacity of the substation is 75.6 MVA is obtained by deducting 60MVA and 24.4MVA from the supplied 160MVA.

5. DETERMINATION OF EDL'S ACTUAL INSTALLED LOADS

To estimate the demand, data related to BUA and land use of buildings in the overall BCD was determined first. For this purpose, a comprehensive site survey was conducted on existing buildings in BCD1; in addition to reviewing the designs of all planned buildings. The land use and current occupancy rates of the already constructed areas in BCD1 are shown in Table 1.

EDL's actual installed load for each of the three selected zones was determined in VA/m^2 at the BCD's HV/MV substation. Table 2 shows a comparison between EDL's VA/m^2 theoretical designs and the calculated VA/m^2 as reflected to the BCD's HV/MV substation.

It is important to note that EDL's theoretical standard adopts 60 VA/m^2 with the addition of miscellaneous loads (ex: basements, elevators) which were approximated by 10%; *i.e.*, a total of 66 VA/m^2.

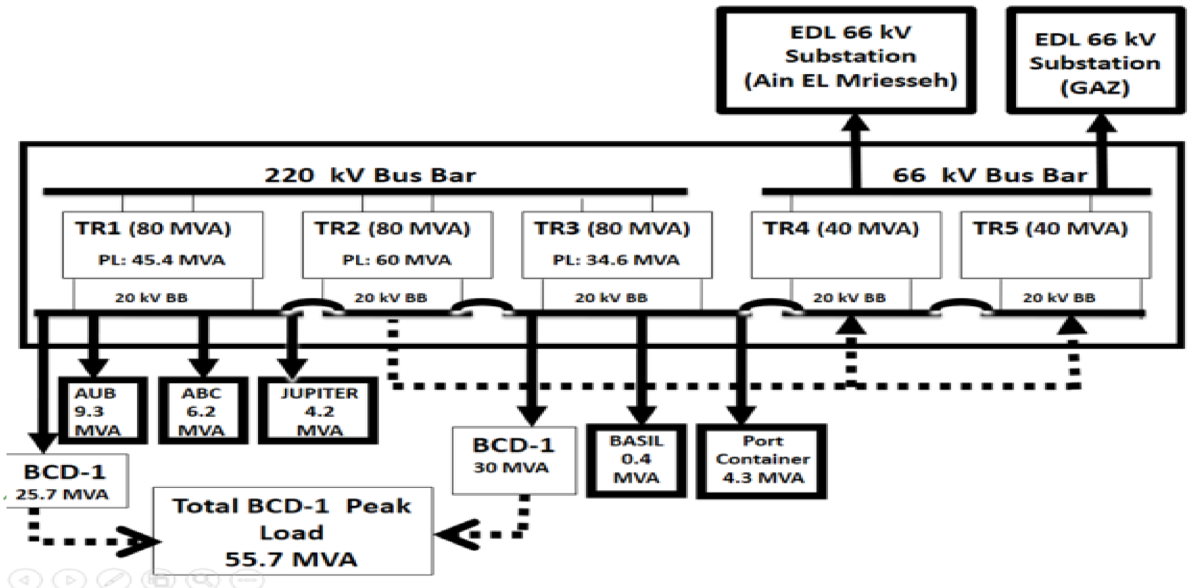

Fig. 1. Peak measured loads supplied to/from the substation during summer 2010.

Table 1. BCD1 current occupancy rates.

Land use	Current Occupancy %
Residential	51
Hotels	95
Retails	62
Offices	77
Governments	100
Miscellaneous (weighted average)	70.4

Table 2. Comparison of estimated and measures loads.

BCD1's Zone Classification	Land Use Description	EDL's Design Figures (VA/m^2)	EDL's Installed Load (VA/m^2)
Zone 1	OB	66	65.80
Zone 2	TLRB	66	81.72
Zone 3	ALRB	66	65.60

Table 3. Assumptions taken to assign buildings' land use and load figures.

Given Land Use	Assigned Land Use	Load figure VA/m^2
Office Governmental Public Administration Cultural Health & W Leisure Congress	Office	65.8
Hotel Commercial/Retail	Hotel Commercial	81.72
Furnished Apartments Residential	Residential	
Mixed Use	70% Residential 30% Office	76.94

Each MV/LV transformer was sized based on EDL's design figures of 66 VA/m^2 according to the following formula:

EDL's MV/LV transformer sizing

$$= \frac{BUA_T \times EDL_{DF}}{1000 \times D_{SL} \times D_{LL} \times T_L} \text{[in KVA]} \quad (1)$$

where:

BUA_T= Total built up area fed from an MV substation,

EDL_{DF}= EDL design figures of 66 VA/m^2,

D_{SL} = Diversity factor at BCD's HV/MV Substation Level (87%),

D_{LL} = Diversity factor at the MV Loop Level (77%),

T_L= Loading of the transformer (85%).

EDL's actual installed load in VA/m^2 as referred to the BCD's HV/MV substation is calculated as:

$$VA/m^2 = \frac{T_R \times 1000 \times D_{SL} \times D_{LL} \times T_L}{BUA_T} \quad (2)$$

where:

T_R = Rating of transformer (s)

Further investigation of the data related to substation's transformers' rating and activities of buildings necessitated the exclusion of some MV/LV substations from this analysis because they were considered out comers which, otherwise, will affect the results of this analysis due to the following reasons:

1. The sizing of these EDL's installed transformers, which was based on EDL design figures of 66 VA/m^2,was much higher than the rated ones, and/or

2. The buildings/establishments were either:

   a) under construction, or

   b) vacant, or

   c) under study, or

   d) under restoration

Breaker loads referred to the MV level of buildings which has been excluded from this analysis because they were under construction were calculated using their corresponding breaker values of 3 x 120 A:

$$\text{Breaker load} = \frac{\sqrt{3} \times I_R \times V_R \times B_L \times D_{LM}}{T_L} \quad (3)$$

where:

IR = Rated current (120 A),

VR = Rated voltage (0.38 KV),

BL = Breaker loading or Breaker utilization (80%),

DLM = Diversity Factor from LV to MV (65%),

TL = Loading of the Transformer (85%).

The corresponding breaker load was 48 KVA, and this value was deducted from the rated value of the corresponding transformer.

6. ASSUMPTIONS MADE

After conducting several site surveys, it has been decided that all residential buildings which will be constructed in the overall BCD are similar to those in zone 2; *i.e.*, top luxurious specifications. Therefore, the estimated load figures (VA/m^2) for existing buildings in zone 3 (average luxurious residential buildings), which were located in BCD1 were not used further in estimating the loads of the overall BCD. Table 3 lists the assumptions taken to assign loads of these buildings according to the type of their land use. Also, to account for the miscellaneous loads (loads for underground public parking lots and other unexpected loads) a 10 MVA figure was added to the overall BCD load.

A load of 55.7 MVA of the already constructed buildings (under current occupancy rates) in BCD1 was used as an initial load in this analysis. This figure has been established from the actual peak load measured readings over three months (June, July, and August) of summer 2010 at MV breakers of BCD's HV/MV substation (refer to Figure 1).

It has been anticipated that the current occupancy rates will increase with time but it will not reach the full occupancy level by 2030 (end of project) due to the type of clients and the luxury of the area, in addition to the political instability in the country and the region. Therefore, the expected occupancy was introduced as the average between the current and full occupancy rates. Table 4 presents the current, expected, and full occupancy rates.

7. LOAD PROFILES OF THE OVERALL BCD

Based on the assumptions presented in the previous section, cumulative load profiles for BCD1, BCD2, and the overall BCD were determined and presented in Figures 2 to 4. Figure 4 shows the sum of cumulative loads presented in Figures 2 and 3 and the miscellaneous loads of 10 MVA for the period 2010-2030.

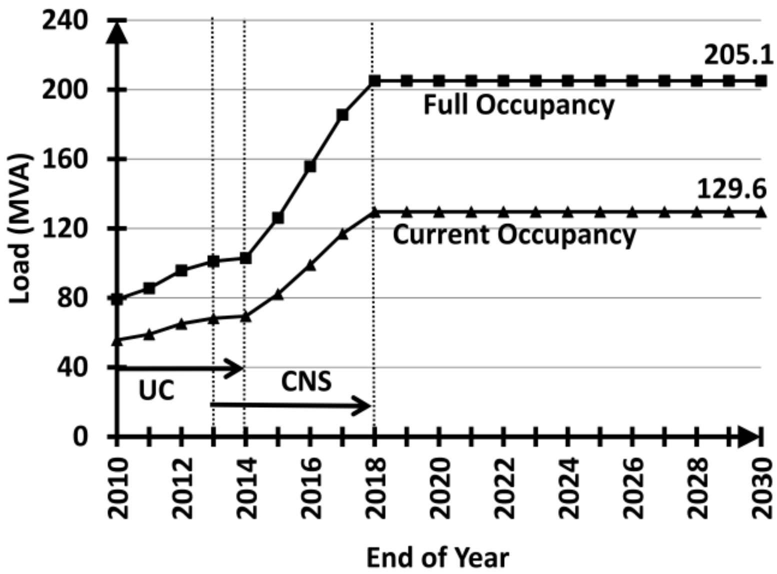

Fig. 2. Load profile of BCD1.

(Note: UC refers to buildings under construction, CNS refers to buildings where construction has not been started)

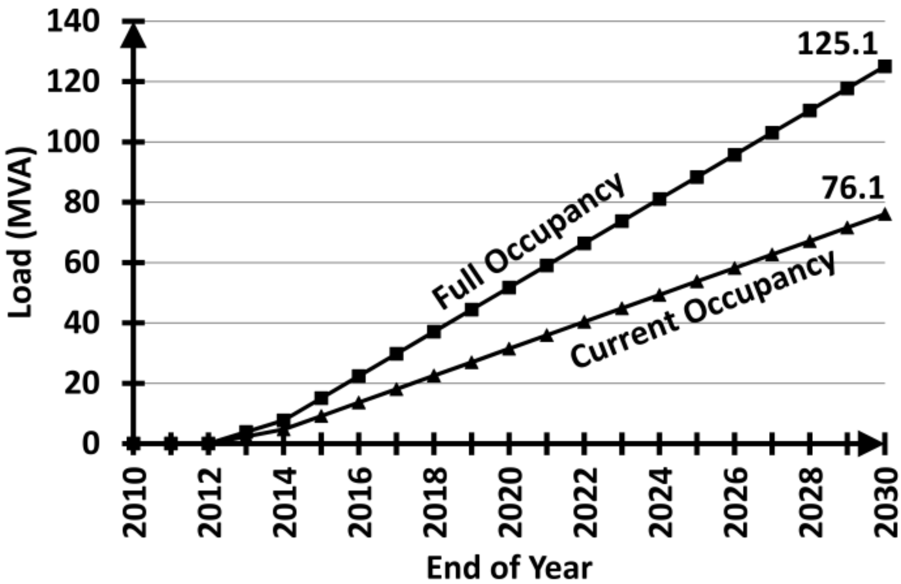

Fig. 3. Load profile of BCD2.

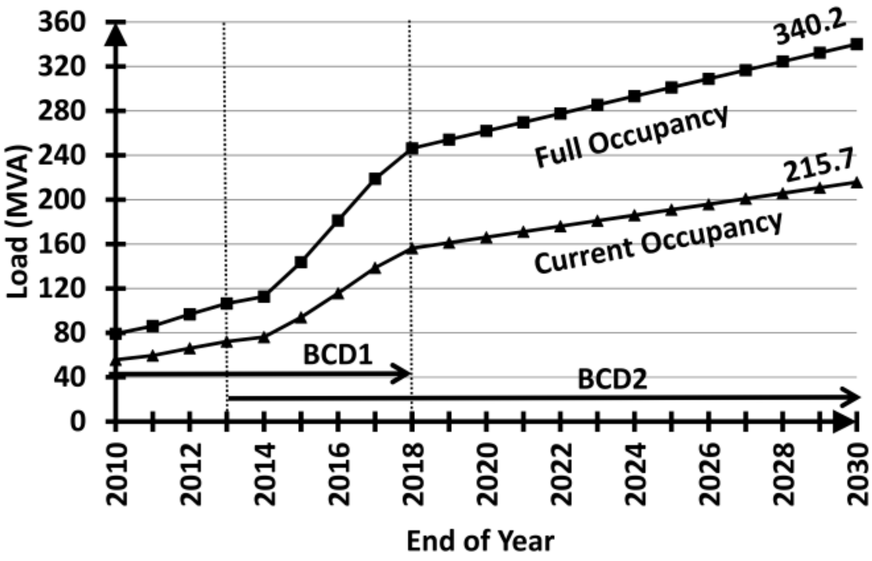

Fig. 4. Load profile of the overall BCD.

If the occupancy rates of the overall BCD remain the same as the current occupancy rates, only 215.7 MVA of load demand will be required by the year 2030 and thus no further expansion will be needed for the existing BCD's HV/MV substation. However, if the occupancy rates of the overall BCD would increase to reach the full occupancy rates (100%), the load demand would then reach 340 MVA by 2030 and thus the capacity of the existing BCD's HV/MV substation (240 MVA) shall be increased to cater for this overall BCD load demand. The average load profiles of these six scenarios are presented in Figure 5.

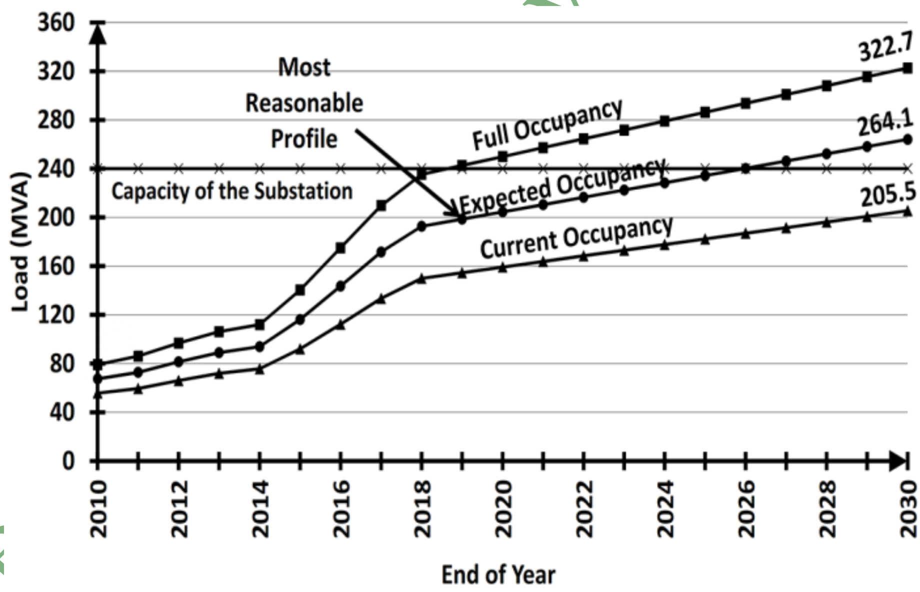

Fig. 5. Average load profiles.

Table 4. Occupancy rates per land use in the Overall BCD.

	Occupancy Rates %		
Land use	Current	Full	Expected
Residential	51	100	75.5
Hotels	95	100	97.5
Retails	62	100	81
Offices	77	100	88.5
Governments	100	100	100
Miscellaneous (Weighted Average)	70.4	100	85.2

8. ANALYSIS, OBSERVATIONS, AND RECOMMENDATIONS

Figure 6 shows the overall BCD's load distribution for the period 2010-2030 which was based on current and expected occupancy rates as stated in Table 4. The full occupancy profile was excluded from Figure 6 because the type of clients/owners (especially the residential land use) reduced the probability of exceeding the expected occupancy rates.

It further determined the end of years' (2010 to 2030) overall BCD's load demand compared to the existing BCD's HV/MV substation's current and maximum available capacity, assuming n+1 redundancy transformers.

As indicated in Figure 6, the load on BCD's HV/MV substation would reach 75.6 MVA (available capacity) by 2014 and thus the substation was not able to feed any additional load afterwards without sacrificing its n + 1 redundancy criterion.

Therefore, EDL must disconnect the loads located outside BCD1 from the substation and feed them from other EDL's sources. Assuming that the loads supplied by the substation to areas located outside BCD1 are removed as recommended above, the substation will be able to supply loads to the overall BCD until its load reaches 160 MVA (maximum available capacity of the substation, assuming n + 1 redundancy).

Figure 6 clarifies this situation and shows that the load would reach the 160 MVA limit between the years 2017 and 2020 with an average of mid 2018 depending, respectively, on whether occupancy rates were expected or current. Accordingly, EDL shall modify the existing 66 KV old bus bar and transformers TR4 and TR5 (Refer to Figure 1) in order to get an overall substation rating of at least 345 MVA.

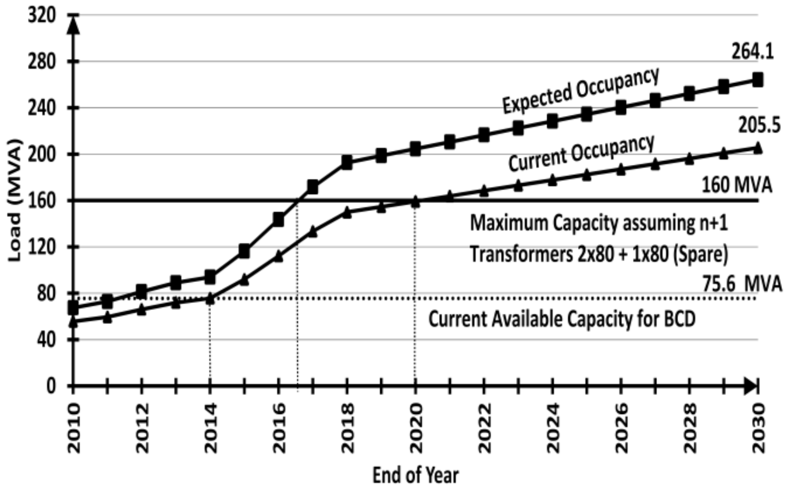

Fig. 6. Major loading observations.

9. CONCLUSIONS

This paper presented a practical approach for determining the expansion capacity of existing HV/MV transformers in the long range planning period (*i.e.* planning spanning over 10 years) of distribution power systems. The new approach estimated the electrical loads based on full occupancy loads of installed MV/LV transformers in existing types of land use buildings. This approach was utilized in determining the expansion capacity of the existing Beirut Central District's HV/MV substation by estimating the electrical loads of Beirut Central District (BCD) which has been undergoing major expansion works for the period starting 2010 and ending in 2030.

Sensitivity analysis has been carried out to determine the best estimates of the calculated loads for the overall BCD over the planning period used to accurately determine the expansion capacity of the existing BCD's HV/MV substation. Substantial savings will be reflected on both the economy and electric power utilities for upgrading HV/MV substations of distribution systems at the right time.

Based on the outcomes of this approach, two actions are recommended to be taken by the Lebanese electric utility:

1. To immediately remove the loads supplied by BCD's HV/MV substation to areas outside the overall BCD and to supply them from other EDL's sources.

2. During 2016, and for the purpose of meeting a load demand of at least 264 MVA by 2030 for the overall BCD, EDL shall release a tender to modify existing BCD's HV/MV substation to become at least 345 MVA.

REFERENCES

[1] Akkawi M.A. and Z. Jaber. 2005. GIS: an integrated tool for power system planning based on spatial customer information. In the *Proceeding I of the 3rd International Conference on Education and Information Systems, Technologies and Applications (EISTA*, Orlando, Florida, USA. 14-17 July: pp 103-108.

[2] Alfares H.K. and M. Nazeeruddin. 2002. Electric load forecasting: literature survey and classification of methods. *International Journal of Systems Science* 33(1): 23-34.

[3] Willis H.L., 1984. Comparison tests of fourteen distribution load forecasting methods. *IEEE Transactions on Power Apparatus and Systems* 103(6): 1190-1197.

[4] Moghram I. and S. Rahman. 1989. Analysis and evaluation of five short term load forecasting techniques. *IEEE Transactions on Power Systems* 4: 1484-1491.

[5] Hahn H., Meyer Nieberg S., and Pickl S., 2009. Electric load forecasting methods: tools for decision making. *European Journal of Operational Research* 199(3): 902-907.

[6] El Naggar K.M. and K.A. Al Rumaih. 2005. Electric load forecasting using genetic based algorithm, optimal filter estimator and least error squares technique: comparative study. *World Academy of Science and Technology*: 138-142.

[7] Chui F., Elkamel A., Surit R., Croiset E., and Douglas P.L., 2009. Long term electricity demand forecasting for power system planning using economic, demographic and climatic variables. *European Journal of Industrial Engineering* 3(3): 277-304.

[8] Sonika D., Darshan S., and Daljeet K., 2015. Long term load forecasting using fuzzy logic methodology. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering* 4(6): 5578-5585.

[9] Tuunanen J., Honkapuro S., and Partanen J., 2015. A novel long-term forecasting process for electricity distribution business. In the *3rd International Conference on Electricity Distribution* (CIRED). Lyon, France. 15-18 June: pp. 1-5.

[10] Hong T., Wilson J., and Xie J., 2014. Long Term probabilistic load forecasting and normalization with hourly information, *IEEE Transactions on Smart Grid* 5(1): 456-462.

[11] Haida T. and S. Muto. 1994. Regression based peak load forecasting using a transformation technique. *IEEE Transactions on Power Systems* 9: 1788-1794.

[12] Electricité du Liban (EDL), 2009. Generation and Transmission Master Plan for the Electricity Sector. *Generation Master Plan Report*: 1-85. Beirut, Lebanon.

[13] Ministry of Energy and Water of Lebanon, 2010. Policy Paper for the Electricity Sector: 1-16.