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Feasibility Studies on the Proposed Developments to Be Added In the Existing Electrical Network by Using ETAP

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Abstract **-** This paper reviews the existing 11kV cabling and 11kV switchgear of the given electrical network to assess the present capacity to carry continuous load, and the effect that new developments will consequently have on the existing network's ability to support the additional loads by using ETAP. This paper has been produced to set out the results of a modelling exercise that has been undertaken on one of our client's main 11kV distribution network. Load flow assessment shows that out of 8 proposed developments (PDs), four PDs can be accommodated in the existing network while four PDs cannot be accommodated in the existing network individually. It is found that in this study the existing network in some places is near its capacity, and indeed for some sections of the network the 11kV cabling is likely to overload under certain switching scenarios, especially when the existing's network embedded generation is not operating. This presents the existing network with significant issues when switching the network for maintenance purposes or to isolate a fault. It also demonstrates that this network needs to ensure that its embedded generation has a very high availability.

Keywords**:** Load flow analysis, ETAP, Capacity of network, Embedded generation, Feasibility studies

1. Introduction

To assess the future growth of any network and for carrying out the feasibility studies, load flow analysis is generally carried out [1]-[8]. In this work, load flow analysis is done for one of our client networks by using Newton Raphson method in ETAP. This is done to determine the feasibility of the 8 proposed developments that are supposed to be added to the existing clients network.

The client owns and operates a private 11kV distribution network. The network is connected to the local Distribution Network Operator's (DNO's) via several individual points of connection to the DNO owned 11kV busbar which forms part of the DNO's 33/11kV Primary substation (see Fig.1).

The WPD 11kV Primary busbar is supplied from two individual 33/11kV transformers and operated under a delta star arrangement, providing full resilience to the site. It is noted that this substation is not dedicated to and solely supplying the existing network, as several other customers are also served via this substation. The points of common coupling between the client's network and the WPD network are the outgoing circuit breakers that feed its network. There are five of these at present, each being provided with its individual tariff metering.

This paper will provide the following information: -

An assessment of the load carrying capability of the existing network cabling and switchgear, to identify the theoretical capacity of the network, and any restrictions that there are to capacity. This will identify any of the existing cabling that will require replacement to enable the increased loads to be carried under the existing configuration. For this purpose, different scenarios considering different combination of proposed developments that needs to be added to the existing network are analysed. The network has been modelled using ETAP 20.6 software to calculate the load flows at the various nodes in the network. This is done with the proposed developments as described in the next section.

2. Existing Network configuration and Proposed Developments

The present configuration of the 11kV network is indicated on the schematic single line diagram in Fig.1. The given network typically operates with 4 Normal Operating Points (NOPs), feeding the network from either side of the ring (i.e., Left Hand side (LHS) and Right-Hand Side (RHS). For each ring these are located at:

- Ring 1 at spare SS between SS 23 and 46 (NOP 1); Ring 2 at SS 7 (NOP 2); Ring 3 at SS 12 (NOP 3); Ring 3 at SS 14 (NOP 4).
- Ring 1 (Green color in Fig.1); Ring 2 (Pink color in Fig.1); Ring 3 (Sky blue color in Fig.1)

The ETAP model has been used to undertake load flows under both normal and abnormal ring configurations. For abnormal conditions a worst-case load flow has been targeted, where the NOP is closed, and the complete ring is fed via a single source either from LHS or RHS. Load flow results are found out for normal scenario and worst scenario. Reason for finding the results for worst-case scenario is that it helps in knowing the worst condition under which the network can function, and this condition is compared with the normal scenario so that conclusions regarding the accommodation of the proposed developments in the network can be made. Here, 8 no. of proposed developments detailed by the client, are briefly described. Proposed developments 1 to 6 represents the various additional loads proposed to be connected to the existing network. Proposed developments 7 and 8 represents the new PV Array's (embedded generation) proposed to be connected to the existing network. Brief description of proposed developments is given below:

1. **Proposed Development - 1** (Additional Load 400 kVA peak -Ring 2) (PD 1)
   Proposed new Substation is connected between SS 10 and SS 9 on Ring 2 via a new RMU.

2. **Proposed Development - 2** (Additional Load 1000 kVA peak - Ring 1) (PD 2)
   Proposed Substation is connected between SS 43 and SS 1 on Ring 1 via a new RMU.

3. **Proposed Development –3** (Additional Load 1.6 MVA peak - Ring 1) (PD 3)
   Proposed connection is via a spare circuit breaker at SS 23, between SS 23 and SS 46 on Ring 1.

4. **Proposed Development - 4** (Additional Load 3.3 MVA peak - Ring 2) (PD 4)
   Proposed Substation is connected radially to SS 39 on Ring 2.

5. **Proposed Development - 5** (Additional Load - Ring 3) (PD 5)
   Proposed Substation is connected between SS 32 and SS 38 on Ring 3, via a new RMU.

6. **Proposed Development - 6** (Additional Load 0.6 MVA Peak - Ring 3) (PD 6)
   Proposed Substation is connected between SS 14 and SS 13 on Ring 3 via a new RMU.

7. **Proposed Development - 7** (PV ARRAY 3 MVA Peak - Ring 3) (PD 7)
   Proposed PV array is connected between SS 37 and SS 22 on Ring 3 via a new 4 section switch panel.

8. **Proposed Development - 8** (PV ARRAY 3 MVA Peak– Ring 2 and 3) (PD 8)
   Proposed PV array is connected between SS 8 (Ring 2) and SS 27 (Ring 3) via a new 4 section switch panel.

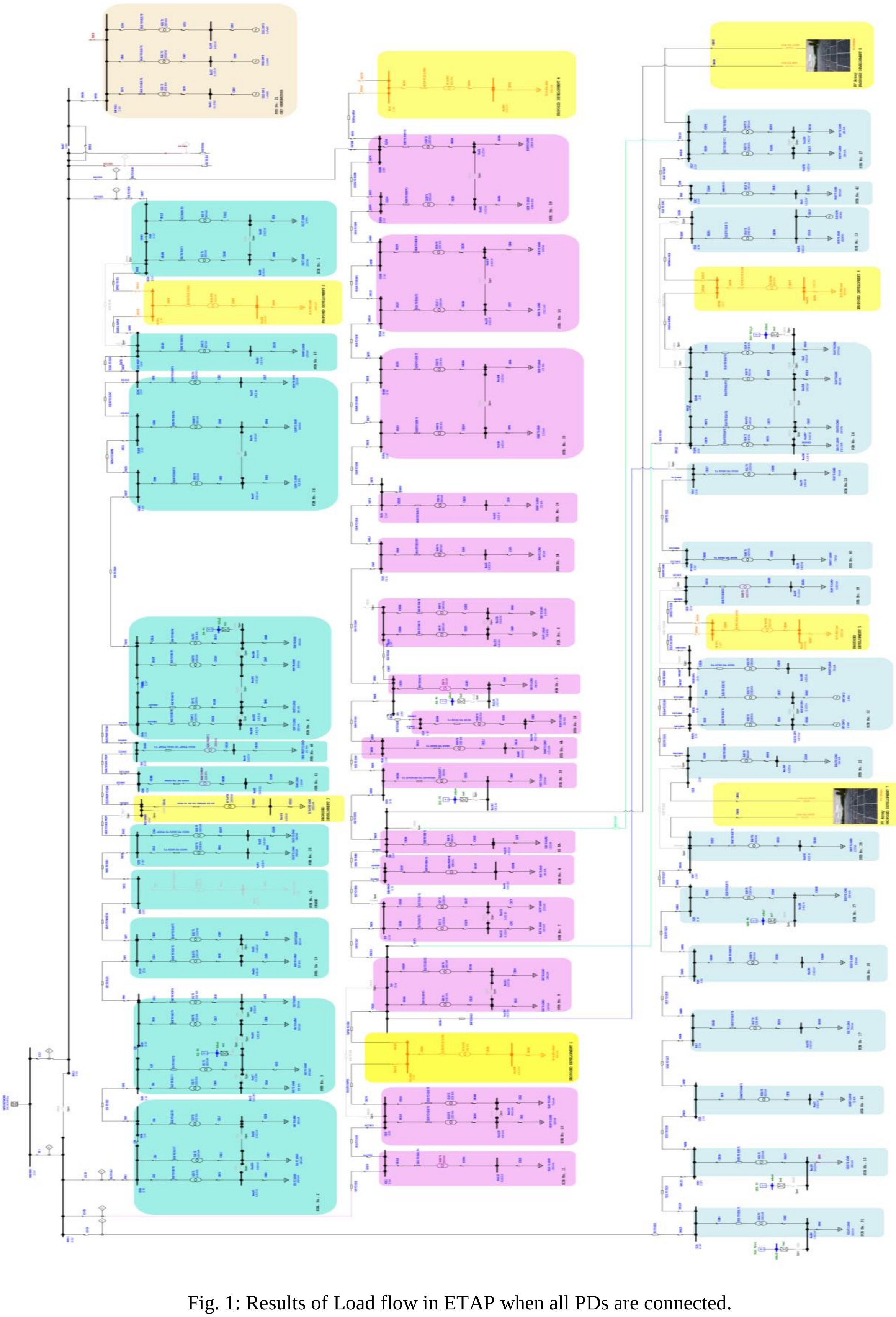

Fig. 1: Results of Load flow in ETAP when all PDs are connected.

Let us now discuss the different scenarios for which results are found out.

NORMAL SCENARIO RATING (A):

In this scenario, results of load flow analysis for the operation of the existing network are assessed, with all the four NOPs in open position and with all the embedded generation connected to the network.

LOADING WITH PROPOSED DEVELOPMENT NORMAL SCENARIO (A):

In this scenario, results of load flow analysis for normal operation of the network are assessed when each proposed development is connected individually at a time to the network, with all the four NOPs in open position and with all the embedded generation connected to the network.

LOADING WITH PROPOSED DEVELOPMENT 1 TO 6 NORMAL SCENARIO (A):

In this scenario, results of load flow analysis for normal operation of the network are assessed when proposed developments (1 to 6 i.e., all the additional loads) are connected in unison to the network, with all the four NOPs in open position and with all the embedded generation connected to the network.

LOADING WITH PROPOSED DEVELOPMENT WORST SCENARIO (A):

In this case results of load flow analysis for operation of the network assessed under worst scenario. For this scenario, it is considered that no embedded generation is connected, NOPs are closed for different PDs, so that maximum load is connected to the given network at a time for the respective PD (1 to 8) connected each at a time.

Also, it is ensured that network is fed only from one source either from LHS or RHS.

WORST SCENARIO RATING % OF DEFINED RATING:

Here, percentage of worst scenario rating in terms of defined rating of the cable is assessed. This helps us to identify how much percentage the cable is overloaded in worst scenario with respect to the defined rating of the cable.

Defined rating of the cable is ampacity of the cable depending upon its size and type.

3. Summary of the results (Normal and Worst Scenarios)

In this section summary of the results for various configurations of the proposed development as briefly discussed in previous section are shown for normal and worst scenarios (Table 1 to 4).

Table 1: Load flow results in ETAP for Ring 1 (Normal and Worst scenarios)

RING No.	LOAD FLOW CONFIGU RATION	FED FROM LEFT OR RIGHT OR BOTH SIDES	SCENARIO (WORST or NORMAL)	NOP POSITION (OPEN or CLOSE)	EMBEDDED GENERATION CONNECTED or NOT CONNECTED	CAN BE ACCOMO DATED IN THE NETWOR K YES OR NO	REFERENCE /INFERENCE
1 (Green color) (Fig.1)	PD 2 alone	Both	Normal	All NOPs open	All connected	Yes	No cable is overloaded.
	PD 3 alone	Both	Normal	All NOPs open	All connected	Yes	No cable is overloaded.
	PD 2 and 3 together	Both	Normal	All NOPs open	All connected	Yes	No cable is overloaded.
	PD 2 alone	Left (U1)	Worst	All NOPs closed	None connected	Yes	2 cables operating above 50 % of defined ratings
	PD 2 alone	Right (U2)	Worst	All NOPs closed	None connected	Yes	5 cables operating above 50 % of defined ratings
	PD 3 alone	Left (U1)	Worst	All NOPs closed	None connected	Yes	3 cables operating above 50 % of defined ratings
	PD 3 alone	Right (U2)	Worst	All NOPs closed	None connected	Yes	6 cables operating above 50 % of defined ratings
	PD 2 and 3 together	Left (U1)	Worst	All NOPs closed	None connected	Yes	No cable is overloaded.
	PD 2 and 3 together	Right (U2)	Worst	All NOPs closed	None connected	Yes	No cable is overloaded.

Table 2: Load flow results in ETAP for Ring 2 (Normal and Worst scenarios)

RING No.	LOAD FLOW CONFIGURATION	FED FROM LEFT OR RIGHT OR BOTH SIDES	SCENARIO (WORST or NORMAL)	NOP POSITION (OPEN or CLOSE)	EMBEDDED GENERATION CONNECTED or NOT CONNECTED	CAN BE ACCOMODATED IN THE NETWORK YES OR NO	REFERENCE /INFERENCE
2 (Pink color- Fig.1)	PD 1 alone	Both	Normal	All NOPs open	ALL connected	Yes	No cable is overloaded.
	PD 4 alone	Both	Normal	All NOPs open	ALL connected	No	1 cable on RHS U4 cable ISS to SS39 is overloaded.
	PD 1 and 4 together	Both	Normal	All NOPs open	ALL connected	No	1 cable on RHS U4 cable ISS to SS39 is overloaded.
	PD 1 alone	Left (U3)	Worst	All NOPs closed	None connected	No	4 cables are overloaded.
	PD 1 alone	Right (U4)	Worst	All NOPs closed	None connected	No	10 cables are overloaded.
	PD 1 alone	Left (U5)	Worst	All NOPs closed	None connected	No	15 cables are overloaded,
	PD 4 alone	Left (U3)	Worst	All NOPs closed	None connected	No	3 cables are overloaded.
	PD 4 alone	Right (U4)	Worst	All NOPs closed	None connected	No	10 cables are overloaded.
	PD 4 alone	Left (U5)	Worst	All NOPs closed	None connected	No	15 cables are overloaded, and some buses are operating at undervoltage.

Table 3: Load flow results in ETAP for Ring 3 (Normal and Worst scenarios)

RING No.	LOAD FLOW CONFIGURATION	FED FROM LEFT OR RIGHT OR BOTH SIDES	SCENARIO (WORST or NORMAL)	NOP POSITION (OPEN or CLOSE)	EMBEDDED GENERATION CONNECTED or NOT CONNECTED	CAN BE ACCOMODATED IN THE NETWORK YES OR NO	REFERENCE /INFERENCE
3 (Sky blue color-Fig.1)	PD 5 alone	Both	Normal	All NOPs open	ALL connected	Yes	No cable is overloaded.
	PD 6 alone	Both	Normal	All NOPs open	ALL connected	Yes	No cable is overloaded.
	PD 5 and 6 together	Both	Normal	All NOPs open	ALL connected	Yes	No cable is overloaded.
	PD 5 alone	Left (U5)	Worst	All NOPs closed	None connected	No	17 cables are overloaded.
	PD 5 alone	Left (U3)	Worst	All NOPs closed	None connected	No	3 cables are overloaded.
	PD 5 alone	Right (U4)	Worst	All NOPs closed	None connected	No	12 cables are overloaded.
	PD 6 alone	Left (U3)	Worst	NOP 2,3 closed, NOP 4 open	None connected	No	3 cables are overloaded.
	PD 6 alone	Right (U4)	Worst	NOP 2,3 closed, NOP 4 open	None connected	No	10 cables are overloaded.
	PD 6 alone	Left (U5)	Worst	NOP 2, 3 closed, NOP 4 open	None connected	No	15 cables are overloaded.

4. Summary of all PDs connected together

Summary of all PDs connected is represented in Table 4 below.

Table 4: Load flow results in ETAP when all PDs connected.

S. No.	LOAD FLOW CONFIGURATION	FED FROM LEFT OR RIGHT OR BOTH SIDES	SCENARIO (WORST or NORMAL)	NOP POSITION (OPEN or CLOSE)	EMBEDDED GENERATION CONNECTED or NOT CONNECTED	CAN BE ACCOMODATED IN THE NETWORK YES OR NO	REFERENCE /INFERENCE
1	PD 1 to 6 together (All additional load PDs)	Fed from both sides	All together	All open	All connected	No	1 cable with ID ISS to SS39 is overloaded.
2	PD 1,2, 3 ,5 and 6 (All additional load PDs without PD 4)	Fed from both sides	All together	All open	All connected	Yes	No cable is overloaded.

5. Conclusion

This paper presents how to determine whether the existing network is feasible enough to accommodate the proposed developments to it by using ETAP, they may be additional loads or embedded generation. It is found that the proposed developments 1 to 6 (except PD 4) can be added to the existing network in each of the ring individually under normal scenario i.e., when all the NOPs 1,2,3 and 4 are in open position and embedded generation is connected. PD 4 cannot be accommodated as one cable on RHS U4 (ISS to SS39) gets overloaded. PDs 1 to 6 (all additional load PDs) cannot be added together simultaneously to the given network under normal scenario because U4 cable (ISS to SS39) feeding the Ring 2 on RHS gets overloaded. However, on removing the PD 4 (Stem Development load) which is on the extreme right of Ring 2, it is found that the five PDs 1, 2, 3, 5 and 6 can be connected simultaneously in the normal scenario without overloading of any of the cable. On considering both normal and worst scenarios it is found that PD 1, PD 4, PD 5 and PD 6 cannot be accommodated in the existing network individually while PD 2, PD 3, PD 7 and PD 8 can be accommodated in the existing network individually.

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