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Analysis of Frequency and Voltage Control in Isolated Micro Grids

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Abstract: Renewable energy supply is environment friendly and promises a sustainable energy for future generation. However, connecting renewable energy resources to exiting power grid may cause technical issues which needs to be solved. The architecture of existing electricity power networks is based on large centralized power generations whereas renewable energy resources are relatively small, distributed and connected to the medium or lower voltage sides. Most renewable energy resources, e.g., PV systems, employ power electronic converters for power conditioning and interface with the grid. Further, renewable energy generation (e.g., from solar and wind) is intermittent in nature and hard to predict. These issues create a challenge for the integration of renewable energy sources into the grid as they can make power system operation and control more complicated and maintaining high quality of supply more difficult. Therefore, new power dispatching strategies and inverter control systems are essential in renewable power energy applications. A distribution network model has been developed in MATLAB/Simulink and implemented to evaluate the voltage profiles and power flow for different levels of PV systems. This will help in evaluating the impact of high penetration levels of small-scale grid connected PV systems on the power quality for a residential distributed network in the UK. Different penetration scenarious are variable load conditions are considered. The computer model developed has been validated by comparison with a reliable model that was developed using ERACS Software package. The result obtained confirmed that maintaining a stable operation and acceptable power quality in distribution networks are possible with a wide range of PV penetration levels.

INTRODUCTION

Renewable energy promises an environmentally friendly energy future for the world. However, many technical issues still must be solved. One of the most renewable energy sources is the solar and wind are intermittent in nature[1]. This is a challenging issue for integration renewable energy sources into the grid and increased the difficulties for maintaining power quality and power system operational control. The micro grid concept is an optimal solution has been proposed to utilize renewable energy sources with smart way to the utility grid, it could be import or export power from and to utility grid. It makes use of two concepts, grid mode and island mode[2, 3].

ltages at different nodes of the distribution network corresponding to the daily load and PV generation profiles were calculated under different PV penetration scenarios[2, 4]. Typical daily Summer and Winter load profile for a domestic load in the UK are adopted[3, 5]. Validate the system results between the utilization of ERACS Software package and the Simulink-MATLAB for a static load. Many scenarios are achieved by the penetration of PV on the low voltage side 230/400 V which are 25, 50 and 100% to each node of the model. Disconnection the low voltage side from the utility and supplied by the diesel generator which is firstly supplied the demand by the require power[6]. Then reduces the output power generation from the diesel generator to investigate the frequency deviation and voltage fluctuations for each bus bar node[7, 8]. Finally, added energy storage system such as battery or flywheel to save the power when there is sufficient power generation and supply electrical power to the system when there is shortage or mismatching between the supply and the demand[9, 10].

MATERIALS AND METHODS

Experimental work: Typical distribution network model as shown in the figure below is considered. The network model includes the distribution network from the primary voltage level (33 kV) three phase source representing the grid supply with a maximum short circuit level of 500 MVA to the low voltage level (400 V) as a line voltage (phase to phase voltage) and (230 V) as a phase voltage (phase to ground voltage).

The 33/11 kV includes two symmetrical step-down 3. Power transformers with a capacity of 20 MVA. The 33/11 kV substation has six 11 kV outgoing feeders consists of 4 km of underground cable, the first 2000 m with 3-Core XLPE cu cable 185 and the second part 2000 m with 3-Core XLPE 95 cu cable, each feeder suppling 8 step-down distribution transformers 11/0.4 kV with capacity of 500 kVA. The substation 11/0.4 kV consists of four 400 V outgoing radial feeders and supplies 410 customers in total (Fig. 1).

In the first scenario of simulation, power system model considered the demand is static loads taking into consideration the minimum and the maximum load demand (0.2-1.4 kVA) for each customer.

Because of the unidirectional design of power system network, the voltage reduces with distance from the sending end (generation side) to the receiving end (demand side) and that is predictable and normal according to ohm law. The active and reactive power decreases as well with distance according to the nature of loads. As well as, it can be seen that the sum of active and reactive power generated and consumed in the system equal to zero. Accordingly, the level of active power flow between the two bus bars is usually determined by the phase difference between their corresponding voltages, furthermore, the level of reactive

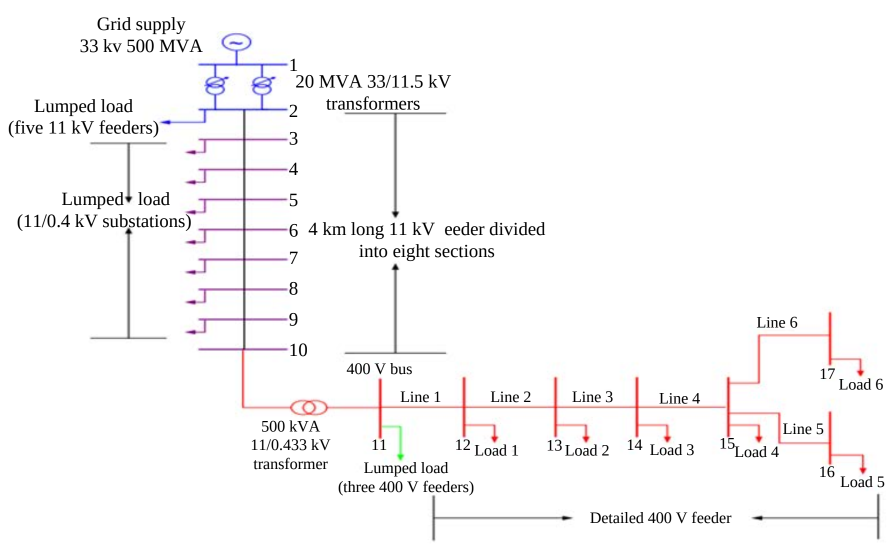

Fig. 1: Typical distribution network in the UK

power flow between them can be measured by calculating the voltage magnitude difference between bus bars. It is obviously noticed that transmission line observes reactive power VAR, cables generate reactive power VAR and transformers absorb reactive power VAR due to shunt magnetizing reactance and series leakage inductance. SCL decreased with the distance and that is predictable and normal. Figure 2 shows that the pu voltage for each substation bus bar will be varied according to the nature of the demand in which the voltage drops in maximum load are bigger than the voltage drops in the minimum load condition according to demand current value. Therefore, the voltage between bus bar 11 and 12 can determined using the equation below:

$$V_{12} = V_{11} - I\left(R + JXL\right)$$

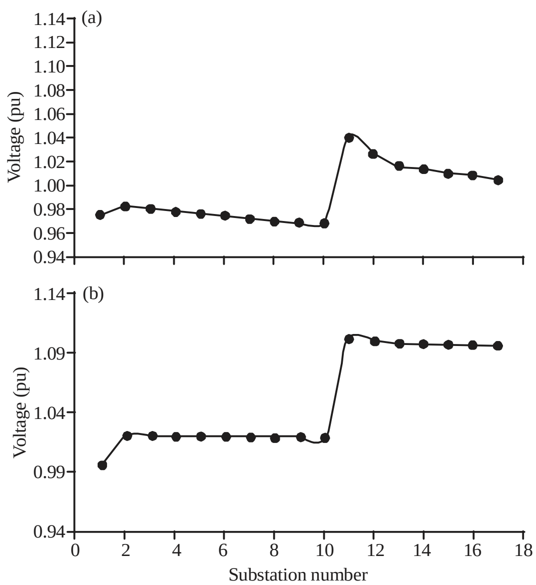

Fig. 2(a-b): Voltage profiles for energic model, (a) Maximum load and (b) Minimum load

Where:

V_{12} : The Voltage at bus bar 12
V_{11}: The Voltage at bus bar 11
I : The current flow between the two bus bar
R&XL : The resistance and reactance of the transmission line, respectively

Model simulation with dynamic load and without PV: The second scenario for simulation of the power system model suppose that the demand is dynamic loads. Figure 3 shows a typical Winter and Summer daily load profile for domestic customers. It uses actual loads for modelling purposes; LV networks are planned based on After Diversity Maximum Demand (ADMD) values that are generally, higher than actual loads.

Model Simulation with dynamic load with different PV penetration: Voltages at different nodes of the distribution network corresponding to the daily load and PV generation profile for a domestic load in the UK adopted. Domestic PV system output profiles specification for Winter and Summer was as:

Winter: Generated from the measured output of a domestic PV system in the UK for the months of December, January and February.

Summer: Generated from the measured output of a domestic PV system in the UK for the months of June, July and August.

System: Size is 2.03 kW, tilt angle 30°, azimuth angle 0° (South facing), output in Wh (average Wh generated in that hour)-average are calculated for the hour centered on the value, i.e., 10 values are the average output between 9:30 and 10:30. Many scenarios are achieved by the penetration of the PV on the low voltage side 230/400 V which are 25, 50 and 100% to each node of the model for a Summer and Winter profile.

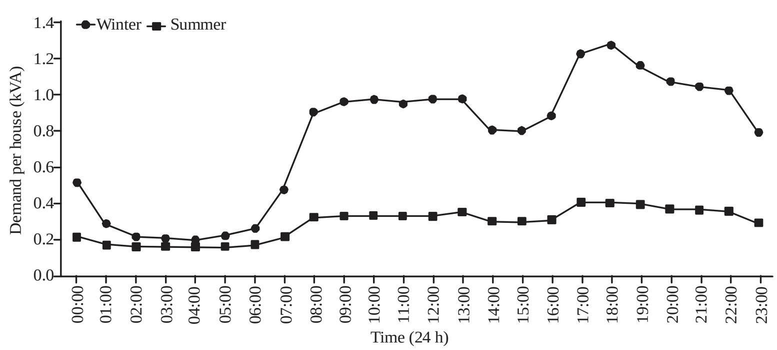

Fig. 3: Typical Summer and Winter daily load profile for a domestic load

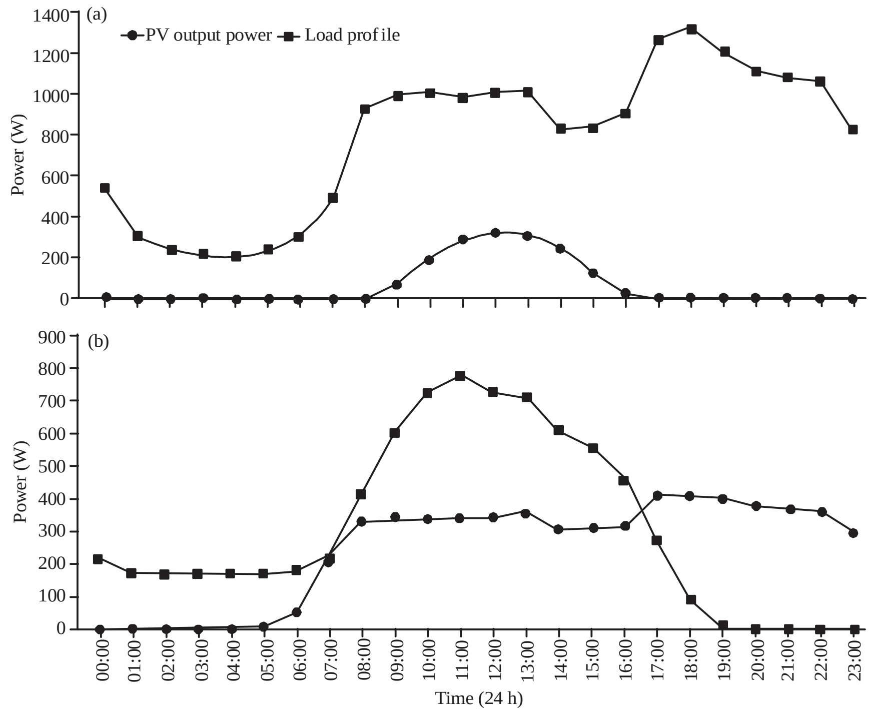

Fig. 4(a-b): Typical daily load profile and PV output power, (a) Winter season and (b) Summer season

Figure 4a and b shows that the 100% PV penetration at low voltage side for both Summer and Winter season. It was noticed that even with connecting PV to the whole customers (100% penetration) in Winter, the voltage profile sustains on the allowable limits. However, different scenario noticed with Summer profile where with 100% the voltage profile exceeds the statuary limit through the period between 10 AM to 2 PM which is the best time for PV generation. It uses actual loads for modelling purposes, LV networks are planned on the basis of After Diversity Maximum Demand (ADMD) values which are generally higher than actual loads.

RESULTS AND DISCUSSION

Figure 1 represents the voltage profile obtained from the modelled network(maximum static load 1.2 kVA) between bus bar 1 and bus bar 17 (farthest point on the LV side). The voltage drop increases further away from the OLTC transformer along the distribution network. However, the voltage increased from bus bar 1 to bus bar 2 according to the role of the tap changer.

Figure 2 shows the voltage profile for minimum static load (0.2 kVA) which are approximately remain the same in both the high and low voltage side according to the low value of the current draws by the demand. However, there is increased in the voltage at bus bar 2 due to the impact of tap changer.

Figure 5 and 6 represents the voltage profile at the low voltage side in Winter and Summer with dynamic load according to typical daily demand for both Summer and Winter voltage profile will be changed. From Fig. 4, it can be seen that the generation of PV generator exceed the Summer demand there will be increased in the voltage profile at these period of time and that could be exceed the statutory limit (1.1 and 0.94 p.u.) depending on the penetration percentages (Fig. 7 and 8).

Model simulation with dynamic load when the grid is disconnected from the utility (Island mode): In this case, the fluctuation in the voltage will increase depending on the size and location of the local distributed generators (Guerrero *et al*., 2012) when the demand is low and the penetration level is high in the distributed generation, there is a possibility to reverse power flow which could cause many protection issues, additionally, the impact of the fluctuation in the frequency will be increased when a mismatching between the generation and the demand.

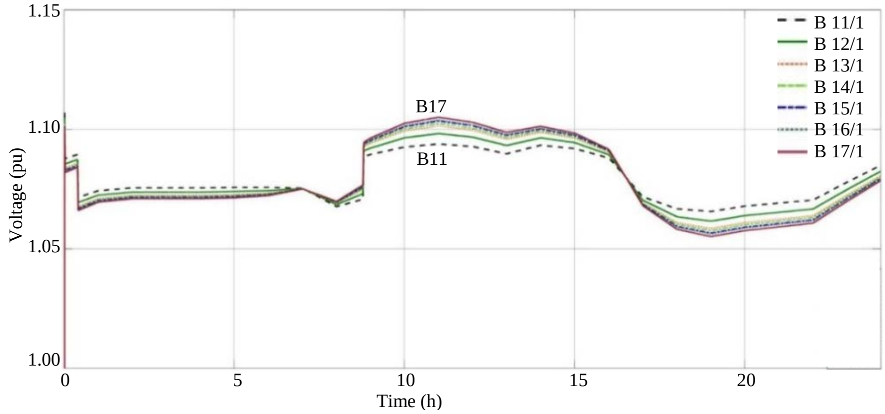

Fig. 5: Voltage profile along the 230/400 V feeder with 100% PV penetration level in Summer (Off-load tap changer)

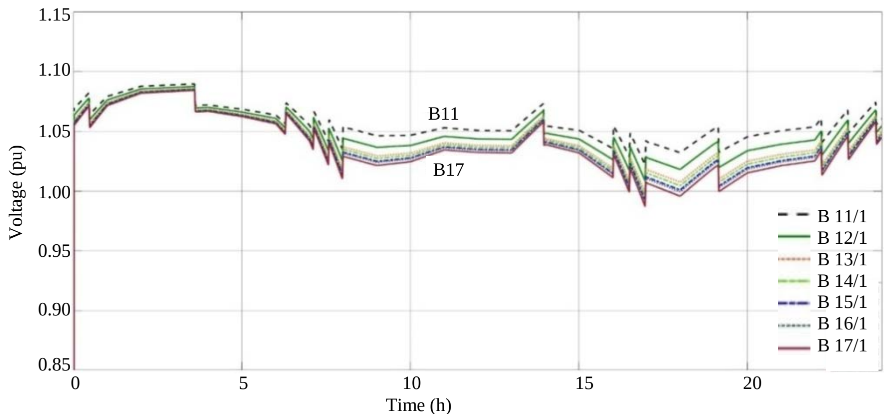

Fig. 6: Voltage profile along the 230/400 V feeder with 100% PV penetration level in Winter (On-load tap changer)

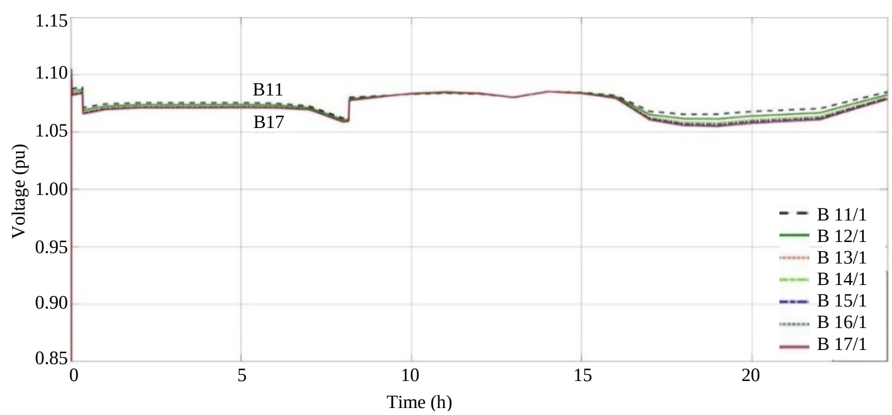

Fig. 7: Voltage profile along the 230/400 V feeder with 50% PV penetration level in Summer (On-load tap changer)

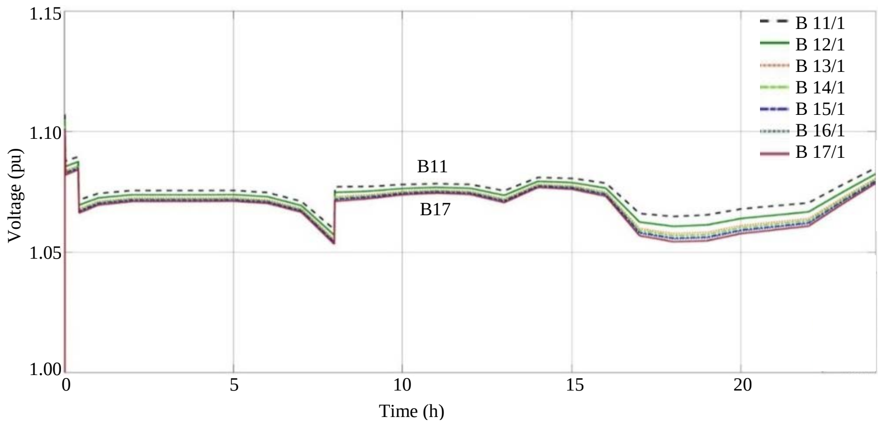

Fig. 8: Voltage profile along the 230/400 V feeder with 25% PV penetration level in Summer (On-load tap changer)

CONCLUSION

Project, a static and dynamic model of a typical UK low voltage distribution network have been developed using ERACS package Software and MATLAB/Simulink. The typical model used to investigate the high penetration levels of grid connected photovoltaic generator on the voltage quality on the low voltage distribution network in the UK. There is possibility to exceed the statutory limits particularly when the demand is low and the generation is high. When the micro grid works in islanding mode, there is a possibility for voltage fluctuation at the low voltage side of the transformer and potential reverse power flow at high generation and low demand. Also, a possible deviation in the frequency of the microgrid. Therefore, that will be controlled by utilize of energy storage unit such as batteries. This will be done as a future work.

REFERENCES

01. Asif, M. and T. Muneer, 2007. Energy supply, its demand and security issues for developed and emerging economies. Renewable Sustainable Energy Rev., 11: 1388-1413.
02. Ter-Gazarian, A.G., 1994. Energy Storage for Power Systems. Peter Peregrinus Ltd., London, Pages: 240.
03. Chowdhury, S. and P. Crossley, 2009. Microgrids and Active Distribution Networks. The Institution of Engineering and Technology, London, United Kingdom, ISBN: 9781849190145, Pages: 320.
04. Conti, S., S. Raiti and G. Tina, 2003. Small-scale embedded generation effect on voltage profile: an analytical method. IEE. Proc. Gen. Transm. Distrib., 150: 78-86.
05. Engler, A. and N. Soultanis, 2005. Droop control in LV-grids. Proceedings of the 2005 International Conference on Future Power Systems, November 18, 2005, IEEE, Amsterdam, Netherlands, pp: 1-6.
06. Guerrero, J.M., J.C. Vasquez, J. Matas, L.G. de Vicuna and M. Castilla, 2010. Hierarchical control of droop-controlled AC and DC microgrids-A general approach toward standardization. IEEE. Trans. Ind. Electron., 58: 158-172.
07. Guerrero, J.M., J.C. Vasquez, J. Matas, M. Castilla and L.G. de Vicuna, 2008. Control strategy for flexible microgrid based on parallel line-interactive UPS systems. IEEE. Trans. Ind. Electron., 56: 726-736.
08. Guerrero, J.M., M. Chandorkar, T.L. Lee and P.C. Loh, 2012. Advanced control architectures for intelligent microgrids-Part I: Decentralized and hierarchical control. IEEE Trans. Ind. Electron., 60: 1254-1262.
09. Han, J., S.K. Solanki and J. Solanki, 2013. Coordinated predictive control of a wind/battery microgrid system. IEEE. J. Emerging Sel. Top. Power Electron., 1: 296-305.
10. He, J., Y.W. Li and F. Blaabjerg, 2014. An enhanced islanding microgrid reactive power, imbalance power and harmonic power sharing scheme. IEEE. Trans. Power Electron., 30: 3389-3401.