A Study on Solutions to Improve Voltage Quality and Continuous Power Supply in Distribution Power Substations

***Nguyen Thi Thanh Thuy**

Electrical Faculty, Thai Nguyen University of Technology, Thai Nguyen, Viet Nam

***Corresponding Author**

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ABSTRACT

This paper proposes some solutions to improve voltage quality and continuous power supply for electric load in distribution power substations. For the solution of using voltage tap changer in the transformer, voltage ratio can be regulated and helps to improve voltage quality for electric loads at the secondary side of the transformer. For the solution of using reserved generator, the structure of power circuit will be proposed to create another source that can replace electric power in case of having a failure at one of transformers. For the solution of using uninterruptible power supplies, their designing structure will be proposed to have many switching operations such as manual/remote/automation to limit the ability to overload and increase their lifetime. A thirteen-bus grid, called E13 grid, will be also introduce in this paper to evaluate operating parameters and the effectiveness of proposed solutions. Simulation carried out by ETAP software will show the meaning of each proposed solution to improve voltage quality for all buses in the grid and ensure continuous power supply in different operating case studies. Power losses in these case studies will be also evaluated to show the overload problem of the uninterruptible power supply in case of having different length of cable after it. Simulation results will make detailed about proposed ideas and their meaning when applied in real distribution power substations.

Index Terms: Continuous power supply, Power transformer, Newton-Raphson, Reserved generator, Uninterruptible Power Supply, Voltage tap changer, Voltage quality.

INTRODUCTION

Introduction

Distribution power grids have been developing widely to meet the increase of both civil and industry electric loads. They can be water pumps, high-price electronic devices. So, the power quality for electric power supply is required more highly than previous time due to the requirements of both technology process and their devices to maintain their lifetime [1-2].

Power quality is characterized by some main factors, such as voltage and frequency deviation, continuous power supply, total harmonic distortion (THD) [2]. Simultaneous value of both voltage, frequency, and THD can be varies in allowable ranges corresponding to normal or fault operating modes. It must be noted that the higher voltage and frequency deviation is, the lower power quality is. Continuous power supply can be evaluated by the capability to meet power for electric loads in all operating modes, including normal, maximum, minimum and fault modes. In case of having failures of main devices in the transmission lines, continuous power supply will be ensured by reserved solutions. According to the circular 39/2015/TT-BCT signed at 18/11/2015 of the Ministry of Industry and Trade, Vietnam, THD of voltage in distribution power grid at medium and low voltage coupling points must be smaller than 6.5% [3]. However, THD at some specical points having advanced electronic devices requires much smaller value than 6.5% to maintain lifetime of electronic boards.

Many studies have shown some solutions to improve power quality such as non-controlled capacitor banks, controlled capacitor banks, reactors, parallel transmission lines, switching method for circuit breakers, voltage tap changer of power transformers, etc [4-14]. Controlled capacitors or reactors are very useful to improve power quality and filtrate harmonic. These devices can make high investment cost, so they are only implemented at some important locations. Recently, power converters have been developed and applied very widely in many fields to regulate photovoltaic and wind power generations, energy storage system (ESS), FACTS devices, etc. They are often coupled in the same structure using DCbus or ACbus parallel to combine DC/DC bidirectional power converters, AC/DC and DC/AC unidirectional power converters [15]. ESSs, lithium battery or accumulator, can be regulated by switches in the DC/DC bidirectional power converter to change its charging or discharging states. They can work as a reserved power generation for electric loads and are called uninterruptible power supply (UPS) [16-19]. UPSs can help to change the direction of power flow from electric grid to ESS without interrupting power at any time or very small time that doesn't affect to electric loads. However, it must be created a suitable designing structure hardware and power system that are evaluated about problems of continuous power supply and capability to be overloaded by simulation tools.

This paper will focus on solutions to improve voltage quality and continuous power supply for electric loads in a distribution power substation. The next section will introduce the method and tool to evaluate voltage quality and continuous power supply in a distribution power substation. This section will also introduce and analyze a thirteen-bus power grid, called E13 grid, by using ETAP software. Section III will propose three solutions to improve voltage quality and continuous power supply, including voltage tap changer of the distribution power transformer, reserved generator and UPSs. This section will show some simulation results and designing solution to avoid overload for UPSs. The last section will present some important conclusions, including evaluations about simulation results and some proposes for designing, operating and the next research problem in the future.

METHOD TO EVALUATE VOLTAGE QUALITY AND CONTINUOUS POWER SUPPLY IN DISTRIBUTION POWER SUBSTATIONS

A. Requirements of voltage quality and continuous power supply

Voltage quality can be evaluated by the value of voltage deviation as depicted in (1) [2]:

$$\Delta U = \frac{|U_n - U|}{U_n} \times 100\% \qquad (1)$$

where: U_n is nominal value of grid voltage; U is simultaneous module value of grid voltage.

The smaller ΔU is, the better voltage quality is. In distribution power grid, allowable value for voltage deviation is 5%. If voltage deviation in some operating modes is higher than 5%, it must apply some operating or designing solutions to decrease this voltage drop.

The solution is often applied to ensure continuous power supply such as increasing the number of transmission line from source to electric loads or using a reserved power source. Considering a power substation as depicted in Fig. 1, where Load2 has an important load that is provided by a line.

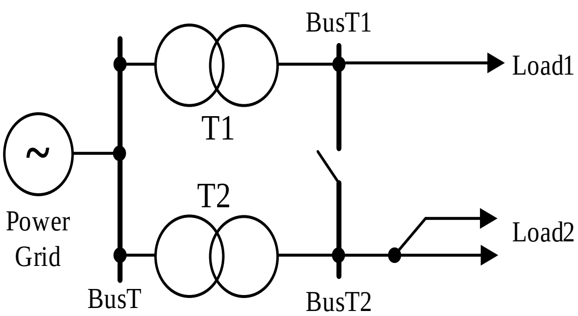

Fig. 1 A general distribution power substation

At normal operating mode, Power of Load1 and Load2 can be supplied from both T1 and T2 transformers. Switch CB is often operated at opened state as represented in Fig. 2.

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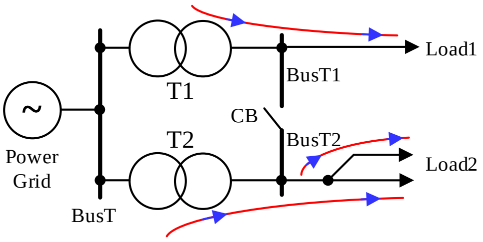


Fig. 2 Power flows in the substation in normal operating state

In case of service out for T2 transformer, important load of Load2 is still supplied from T1 transformer by switching CB on as shown in Fig. 3.

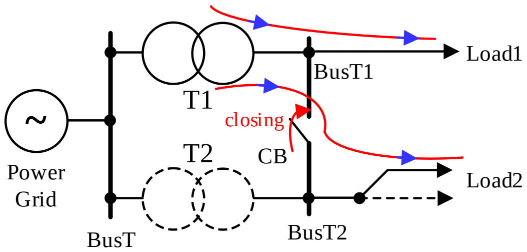


Fig. 3 Power flows in the substation after T2 transformer cut off

In case of cutting a transmission line in the double line connected from BusT2 to Load2, the T2 transformer continuously supplies power for important load in Load2 as depicted in Fig. 4.

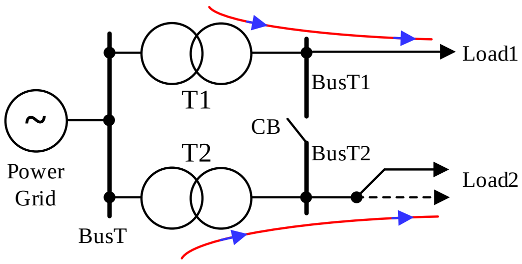


Fig. 4 Power flows in the substation after a transmission line cut off

It is easy to recognize that it must be create other solutions to improve voltage quality, continuous power supply, and reduce power loss. To have this, it must be analyzed and evaluated by mathematical and simulation tools as represented in the next parts.

B. Mathematical tool

Mathematical model of medium voltage transmission lines is described in Fig. 5 [20-21].

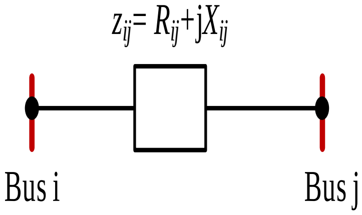
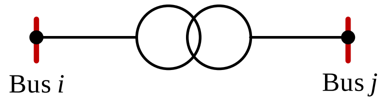


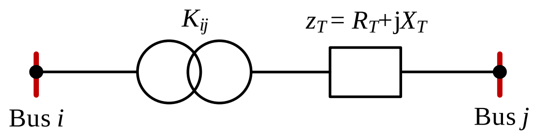
Fig. 5 Mathematical model of transmission line in medium voltage systems

Where: R_{ij} (Ω) is resistance and X_{ij} (Ω) is reactance of the transmission line connecting bus i and bus j.

Mathematical model of two-winding transformer is described in Fig. 6.



a. Power transformer

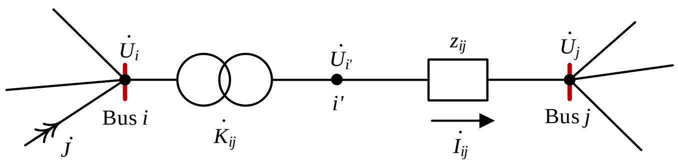


b. Equivalent circuit

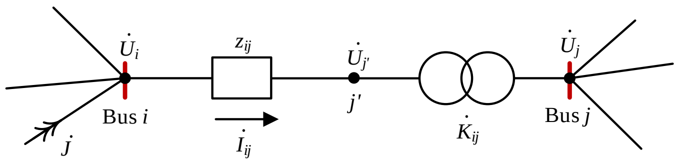
Fig. 6 Mathematical model of two-winding transformer

Where: R_T (Ω) is resistance and X_T (Ω) is reactance of the transformer; K_{ij} is voltage ratio between bus i and bus j of ideal transformer (without power loss). In Fig. 6b, voltage value of bus i is higher than voltage value of bus j, so bus i is called HV bus and bus j is called LV bus.

A general distribution system include (N+1) buses, where N buses are normal buses and a bus is ground. Any branch in the system can be classified to the standard line or transformer branch. These branches can be defined by a general standard branch as depicted in Fig. 7 [20-21].



a. Bus i connecting to the ideal transformer directly



b. Bus i connecting to the ideal transformer indirectly through an impedance

Fig. 7 Diagram of general standard branch

In Fig. 7a and Fig. 7b, the current source $\dot{J}_i$ (from generations) is injects to bus i. If the branch describes a transformer, voltage ratio can be calculated forward to bus i that is $\dot{K}_{ij} = \frac{\dot{U}_{i'}}{\dot{U}_{i'}}$. If the branch describes a transmission line, voltage ratio is $\dot{K}_{ij} = 1$.

Applying Kirchhoff 1, current balancing equation at bus i can be determined by (2) [7].:

$$\sum_{\substack{j=0\\ j\neq i}}^{N} \dot{I}_{ij} = \dot{J}_i \qquad (2)$$

Using I'_{ij}, equation (1) can be converted to equation (3):

$$\sum_{\substack{j=0\\ j\neq i}}^{N} \dot{K}_{ij}\dot{I}'_{ij} = \dot{J}_i \qquad (3)$$

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Using Ohm's law for *i'j* branch, equation (3) can be converted to equation (4) [7]:

$$\dot{Y}_{ii}\dot{U}_{k}+\sum_{\substack{j=0\\j\neq i}}^{N}\dot{Y}_{ij}\dot{U}_{j}=\dot{J}_{i} \qquad (4)$$

where: $\dot{Y}_{ii}$ is individual admittance of bus *i* and $\dot{Y}_{ij}$ is interactive admittance of branch *ij*.

$\dot{Y}_{ii}$, $\dot{Y}_{ij}$ can be determined by equation (5) and (6) [7].:

$$\dot{Y}_{ii}=\sum_{\substack{j=0\\j\neq i}}^{N}\left(\frac{\dot{K}_{ij}^{2}}{\dot{Z}_{ij}}\right) \qquad (5)$$

$$\dot{Y}_{ij}=-\frac{\dot{K}_{ij}}{\dot{Z}_{ij}} \qquad (6)$$

Working the same with Fig. 7b, $\dot{Y}_{ii}$ can be defined by equation (7):

$$\dot{Y}_{ii}=\sum_{\substack{j=0\\j\neq i}}^{N}\frac{1}{\dot{Z}_{ij}} \qquad (7)$$

In general case study, bus *i* can be connected to *m* buses directly through ideal transformers and *k* buses indirectly through ideal transformers. $\dot{Y}_{ii}$ can be determined by equation (8) [20-21]:

$$\dot{Y}_{ii}=\sum_{\substack{j=0\\j\neq i}}^{k}\frac{1}{\dot{Z}_{ij}}+\sum_{\substack{j=0\\j\neq i}}^{m}\frac{\dot{K}_{ij}^{2}}{\dot{Z}_{ij}} \qquad (8)$$

Current balancing equations for whole system can be described in system of equations (9).

$$\begin{cases}\dot{Y}_{11}\dot{U}_{1}+\dot{Y}_{12}\dot{U}_{2}+\ldots+\dot{Y}_{1N}\dot{U}_{N}=\dot{J}_{1}\\ \dot{Y}_{21}\dot{U}_{1}+\dot{Y}_{22}\dot{U}_{2}+\ldots+\dot{Y}_{2N}\dot{U}_{N}=\dot{J}_{2}\\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\\ \dot{Y}_{N1}\dot{U}_{1}+\dot{Y}_{N2}\dot{U}_{2}+\ldots+\dot{Y}_{NN}\dot{U}_{N}=\dot{J}_{N}\end{cases} \qquad (9)$$

From equation (9), matrix admittance can be derived as (10):

$$Y=\begin{bmatrix}\dot{Y}_{11} & \dot{Y}_{12} & \ldots & \dot{Y}_{1N}\\ \dot{Y}_{21} & \dot{Y}_{22} & \ldots & \dot{Y}_{2N}\\ \ldots & \ldots & \ldots & \ldots\\ \dot{Y}_{N1} & \dot{Y}_{N2} & \ldots & \dot{Y}_{NN}\end{bmatrix} \qquad (10)$$

Almost buses in distribution systems are PQ buses (load buses). Capacitors can be implemented at these buses and considered as reactive generators. In these systems, Newton-Raphson method is often used to determine power flows and voltage buses.

To determine operating parameters for *N*-bus grid by using Newton-Raphson method, system of power balancing equations at bus i can be defined by (11) and (12) [7]:

$$U_i^2 y_{ii} \cos\psi_{ii} + \sum_{\substack{j=1 \\ j\neq i}}^{N} U_i U_j y_{ij} \cos(\delta_i - \delta_j - \psi_{ij}) - P_{Li} = \Delta P_i \quad (11)$$

$$-U_i^2 y_{ii} \sin\psi_{ii} + \sum_{\substack{j=1 \\ j\neq i}}^{N} U_i U_i y_{ij} \sin(\delta_i - \delta_j - \psi_{ij}) - (Q_{Li} - Q_{Ci}) = \Delta Q_i \quad (12)$$

where: $i = \overline{1, N}$; $\dot{U}_i = U_i \angle \delta_i ; Y_{ij} = y_{ij} \angle \Psi_{ij}$.

P_{Li} and Q_{Li} are active and reactive load power at the bus i; Q_{Ci} are active and reactive power of the capacitor bank at the bus i.

From solutions at the kth step including $\delta_i^{(k)}$ and $U_i^{(k)}$, values of $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ can be calculated. Moreover, values of $\Delta\delta_i^{(k)}$ and $\Delta U_i^{(k)}$ at the kth step can be calculated by using reversed Jacobian matrix as described in equation (13) [20-21]:

$$\begin{bmatrix} \Delta\delta_i^{(k)} \\ \Delta U_i^{(k)} \end{bmatrix} = J^{-1} \begin{bmatrix} \Delta P_i^{(k)} \\ \Delta Q_i^{(k)} \end{bmatrix} \quad (13)$$

where: J is Jacobian matrix.

Jacobian matrix at the i^{th} step: $J = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix}$

Solutions at the next step can be determined by equation (14) [20-21]:

$$\begin{bmatrix} \delta_i^{(k+1)} \\ U_i^{(k+1)} \end{bmatrix} = \begin{bmatrix} \delta_i^{(k)} \\ U_i^{(k)} \end{bmatrix} + \begin{bmatrix} \Delta\delta_i^{(k)} \\ \Delta U_i^{(k)} \end{bmatrix} \quad (14)$$

This process will be stopped if both values of ΔP_i and ΔQ_i are smaller than allowable value ε [7-9]. Fig. 8 describes the Newton-Raphson method to analyze a distribution system.

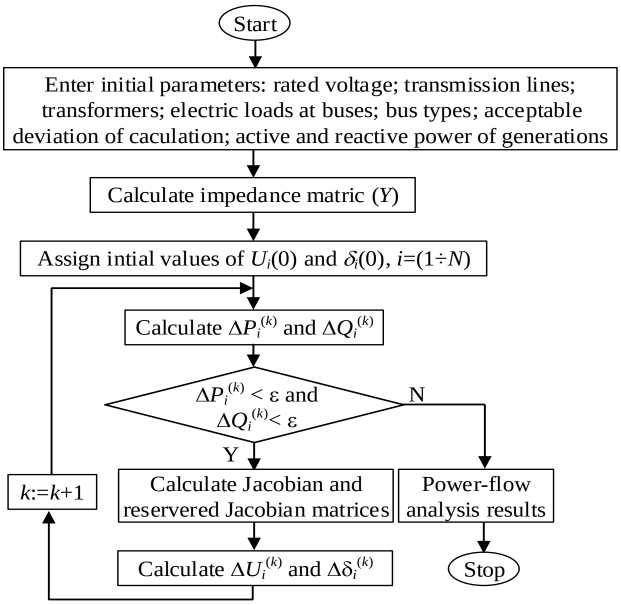

Fig. 8. Newton-Raphson algorithm to analyze whole grid

The Newton-Raphson method possesses a unique quadratic convergence characteristic. It usually has a very fast convergence speed compared to other load flow calculation methods. It also has the advantage that the convergence criteria are specified to ensure convergence for bus real power and reactive power mismatches. This criterion gives you direct control of the accuracy you want to specify for the load flow solution. The convergence criteria for the Newton-Raphson method are typically set to 0.001 MW and MVAr.

C. Using Newton-Raphson and ETAP software to analyze power quality

The Newton-Raphson method is highly dependent on the bus voltage initial values. A careful selection of bus voltage initial values is strongly recommended. Before running load flow using the Newton-Raphson method, ETAP makes a few Gauss-Seidel iterations to establish a set of sound initial values for the bus voltages.

Considering a thirteen-bus distribution power grid, called E13 grid and represented in Fig. 9.

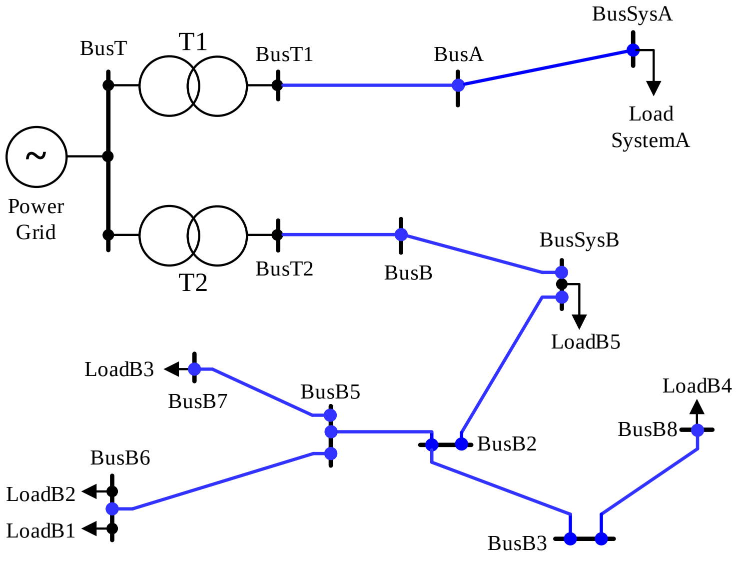

Fig. 9. Diagram of E13 grid

Parameters of transmission lines in Table I, power source in Table II, transformers in Table III, electric load at bused in Table IV.

Table1: Parameters of Transmission Lines

Name	Sectional area of a conductor (mm^2)	Insulation	Length (m)	Number of conductors/phase
BusT1-BusA	300	XLPE	70	5
BusA-BusSysA	300	XLPE	15	5
BusT2-BusB	300	XLPE	80	6
BusB-BusSysB	300	XLPE	20	6
BusSysB-BusB2	300	XLPE	16	2
BusB2-BusB5	300	XLPE	30	2
BusB5-BusB6	185	XLPE	28	1
BusB5-BusB7	185	XLPE	24	1
BusB2-BusB3	185	XLPE	40	2

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BusB3-BusB8	400	XLPE	20	5

Table 2: Parameters of source

Type	Parameters
Power system	Rated voltage: 22 kV; Short-circuit power: 250 MVA; Reactance/Resistance: 10

Table 3: Transformers

Location	Parameters
T1 and T2	Voltage ratio: 110/35 kV; Rated power: 25 MVA; Impedance: Z=10%; Reactance/Resistance=20

Table 4: Parameters of electric load at buses

Name	Apparent power (MVA)	cosφ	Type
Load SystemA	4805	593.3	Static load
LoadB1	10	3.28	
LoadB2	100	32.9	
LoadB3	285	93.67	
LoadB4	304	99.82	
LoadB5	1140.1	374.3	

Using Newton-Raphson method and ETAP to analyze E13 grid at normal operating state, simulation result is represented in Fig. 10.

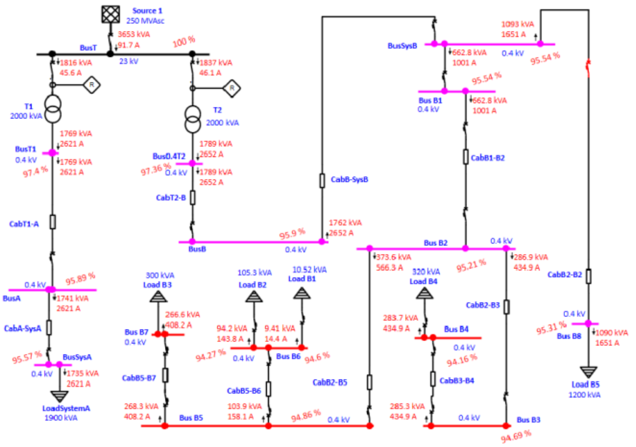

Fig. 10 Simulation result for analyzing E13 grid at normal operating state

From simulation result in Fig. 10, it is easy to note that voltage deviations at Bus B4, Bus B5, Bus B6, Bus B7 are highest (higher than 5%).

Using loss report function in ETAP software, the branch losses summary report in this operating mode is shown in TABLE V. It showed the power loss is 91.5+257.7 kVAr.

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Table 5: Branch losses report in normal operating mode

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
	MW	Mvar	MW	Mvar	kW	kvar	From	To	
CabA-SysA	1.653	0.546	-1.649	-0.542	4.7	4.4	95.9	95.6	0.32
CabB1-B2	0.629	0.210	-0.627	-0.208	1.8	1.7	95.5	95.2	0.33
CabB2-B2	-1.036	-0.340	1.038	0.342	2.0	2.3	95.3	95.5	0.23
CabB2-B3	0.272	0.090	-0.271	-0.089	1.4	0.8	95.2	94.7	0.52
CabB2-B5	0.355	0.118	-0.353	-0.117	1.1	1.0	95.2	94.9	0.35
CabB3-B4	0.271	0.089	-0.270	-0.089	1.4	0.8	94.7	94.2	0.52
CabB5-B6	0.099	0.033	-0.098	-0.032	0.3	0.2	94.9	94.6	0.27
CabB5-B7	0.255	0.084	-0.253	-0.083	1.5	0.9	94.9	94.3	0.59
CabB-SysB	1.672	0.557	-1.666	-0.552	5.4	5.0	95.9	95.5	0.36
CabT1-A	-1.653	-0.546	1.675	0.567	22.0	20.5	95.9	97.4	1.51
CabT2-B	1.693	0.577	-1.672	-0.557	21.5	20.0	97.4	95.9	1.45
T1	1.689	0.666	-1.675	-0.567	14.1	98.9	100.0	97.4	2.60
T2	-1.693	-0.577	1.708	0.678	14.4	101.3	97.4	100.0	2.64
					91.5	257.7			

Assuming faults similar to Part A in this section, simulation result in Fig. 11 showed that all loads after Bus B2 were cut off in case of having failure on BusB1-B2 cable.

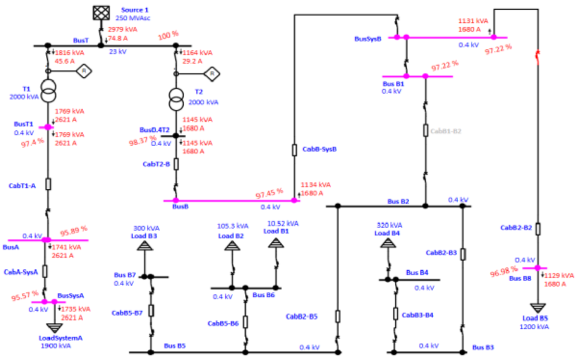

Fig. 11 Simulation result in case of having failure on BusB1-B2 cable

Simulation result in case of having failure on T2 transformer and servicing out is depicted in Fig. 12.

Work similarly

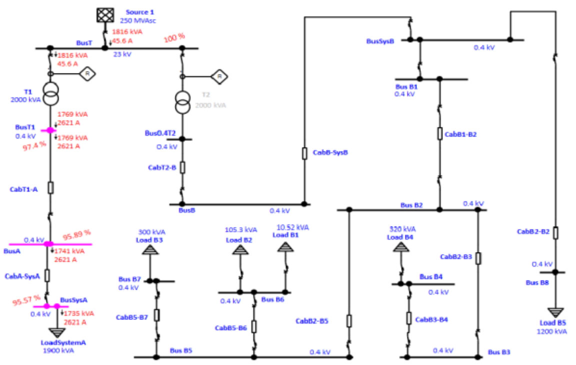

Fig. 12 Simulation result in case of having failure on T2 transformer and servicing out

Above simulation results showed that voltage quality in E13 grid wasn't held in allowable range (voltage deviations were smaller than 5%) and electric loads were cut off in cases of having failure on main transmission lines or main transformer.

Propose solutions to improve power quality for E13 grid

A. Using voltage tap changer

All distribution power transformers are manufactured with the voltage regulator implemented at the primary side to regulate voltage at the secondary side in a limited range. It often has 5 levels that help to increase/decrease $\pm 2,5\% U_n$ as depicted in Fig. 13.

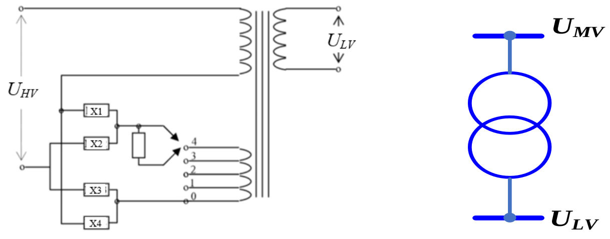

Fig. 13 Voltage regulator in distribution power transformers

If voltage value at the primary side is approximate nominal value, the voltage regulator will be controlled to set at the 2-number location. If voltage value at the primary side is higher than nominal value, the voltage regulator will be controlled to set at the 0-number or 1-number location. If voltage value at the primary side is smaller than nominal value, the voltage regulator will be controlled to set at the 3-number or 4-number location. It must be noted that voltage tap changer of distribution power substations only allows to change winding ratio in de-energizing state (called DETC for de-energized tap changer). So, the change of this regulator is not executed regularly. It is often operated in planning times corresponding to the variation of grid parameters [3], [9], [11-14].

Using Newton-Raphson and ETAP software to simulate E13 grid in case of voltage tap changer at -5%, simulation result is represented in Fig. 14.

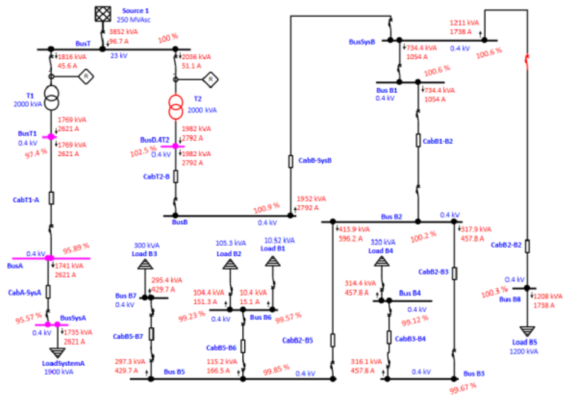

Fig. 14 Simulation result in case of using -5% level of voltage tap changer

Using loss report function in ETAP software, the branch losses summary report in this operating mode is shown in TABLE VI. It showed the power loss is 97+272.2 kVAr.

Table 6: Branch losses report in the mode using voltage tap changer

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
CabA-SysA	1.653	0.546	-1.649	-0.542	4.7	4.4	95.9	95.6	0.32
CabB1-B2	0.697	0.232	-0.695	-0.230	2.0	1.9	100.6	100.2	0.35
CabB2-B2	-1.148	-0.377	1.150	0.379	2.2	2.6	100.3	100.6	0.24
CabB2-B3	0.302	0.100	-0.300	-0.099	1.5	0.9	100.2	99.7	0.55
CabB2-B5	0.393	0.130	-0.392	-0.129	1.2	1.1	100.2	99.9	0.37
CabB3-B4	0.300	0.099	-0.299	-0.098	1.5	0.9	99.7	99.1	0.55
CabB5-B6	0.109	0.036	-0.109	-0.036	0.3	0.2	99.9	99.6	0.28
CabB5-B7	0.282	0.093	-0.281	-0.092	1.6	1.0	99.9	99.2	0.62
CabB-SysB	1.852	0.617	-1.846	-0.612	5.9	5.5	100.9	100.6	0.38
CabT1-A	-1.653	-0.546	1.675	0.567	22.0	20.5	95.9	97.4	1.51
CabT2-B	1.876	0.639	-1.852	-0.617	23.8	22.1	102.5	100.9	1.53
T1	1.689	0.666	-1.675	-0.567	14.1	98.9	100.0	97.4	2.60
T2	-1.876	-0.639	1.892	0.751	16.0	112.2	102.5	100.0	2.48
					97.0	272.2			

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B. Using reserved generator

This generator uses fossil fuel to generate power and is considered as a reserved power generation for main source (power grid). It often includes some main units: rotor, generator, fuel tank, fuel pump, automatic voltage regulator, wind/water cooling system, etc [22].

Using Newton-Raphson và ETAP software to simulate E13 grid in case of having a reserved generator to replace T2 transformer, simulation result is represented in Fig. 14. Parameters of the generator are: rated power 2000 kVA; cosφ=0.95. Parameters of BusG-BusA cable: type XLPE 5×300 mm^2; 31m length. Parameters of BusG-BusB cable: type XLPE 5×300 mm^2; 27.7m length. It is noted that the generator in this system structure must be designed to replace both T1 and T2 transformers if one of them is serviced out.

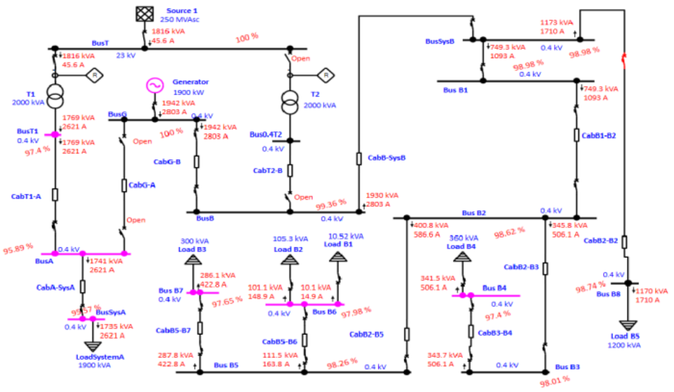

Fig. 15 Simulation result in case of using the reserved generator

Using loss report function in ETAP software, the branch losses summary report in this operating mode is shown in TABLE VII. It showed the power loss is 66+146.3 kVAr.

Table 7: Branch losses report in the mode using a reserved generator

Branch Losses Summary Report

Branch ID	From-To Bus Flow MW	From-To Bus Flow Mvar	To-From Bus Flow MW	To-From Bus Flow Mvar	Losses kW	Losses kvar	% Bus Voltage From	% Bus Voltage To	Vd % Drop in Vmag
CabA-SysA	1.653	0.546	-1.649	-0.542	4.7	4.4	95.9	95.6	0.32
CabB1-B2	0.675	0.225	-0.673	-0.223	2.0	1.8	99.0	98.7	0.34
CabB2-B2	-1.112	-0.365	1.114	0.368	2.1	2.5	98.8	99.0	0.24
CabB2-B3	0.292	0.097	-0.291	-0.096	1.5	0.9	98.7	98.1	0.54
CabB2-B5	0.381	0.126	-0.380	-0.125	1.2	1.1	98.7	98.3	0.36
CabB3-B4	0.291	0.096	-0.289	-0.095	1.5	0.9	98.1	97.6	0.54
CabB5-B6	0.106	0.035	-0.106	-0.035	0.3	0.2	98.3	98.0	0.28
CabB5-B7	0.274	0.090	-0.272	-0.089	1.6	0.9	98.3	97.7	0.61
CabB-SysB	1.795	0.598	-1.789	-0.593	5.8	5.4	99.4	99.0	0.38
CabG-B	-1.795	-0.598	1.805	0.607	9.6	8.9	99.4	100.0	0.63
CabT1-A	-1.653	-0.546	1.675	0.567	22.0	20.5	95.9	97.4	1.51
T1	1.689	0.666	-1.675	-0.567	14.1	98.9	100.0	97.4	2.60
					66.3	146.3			

C. Using UPSs

A basic internal structure of an UPS is represented in Fig. 16 [16-19].

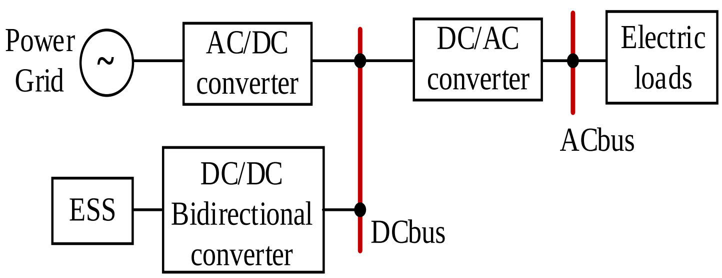

Fig. 16 A basic internal structure of a UPS

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In the operating process, an UPS with basic internal structure has power flows in case of no-load and not full capacity for ESS as depicted in Fig. 17. In this case study, DC/AC power converter still consumes a small power corresponding to power losses in units to maintain its output voltage.

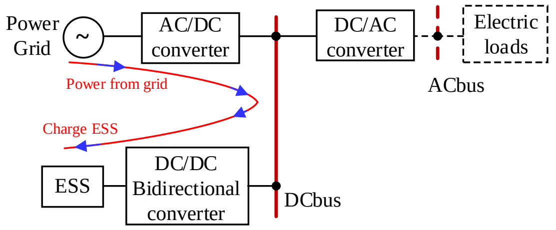

Fig. 17 Power flows in case of no-load and not full capacity for ESS

In the operating process, an UPS with basic internal structure has power flows in case of having load and full capacity for ESS as depicted in Fig. 18. In this case study, DC/DC bidirectional power converter still consumes a small power corresponding to power losses in units to maintain ready state for charging ESS.

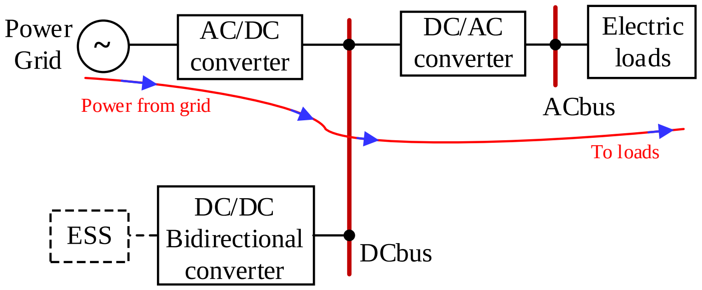

Fig. 18 Power flows in case of having load and full capacity for ESS

In the operating process, an UPS with basic internal structure has power flows in case of having load and not full capacity for ESS as depicted in Fig. 19. In this case study, all power converter still consumes a power corresponding to power losses in units to transmit power from power grid to loads.

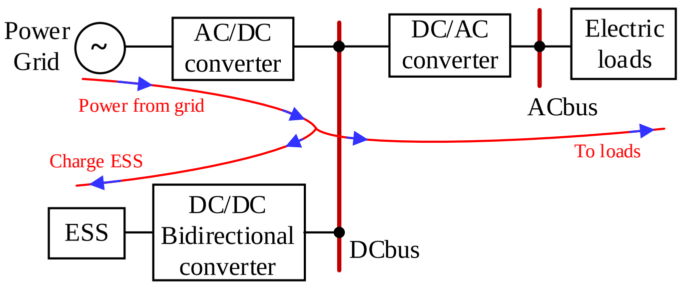

Fig. 19 Power flows in case of having load and not full capacity for ESS

Due to above analysis, UPSs always cause a mount of power losses and it must be applied a control method to avoid failures for their power converters when having external faults at their load side. Some bypass switches are proposed as depicted in Fig. 20 to execute this idea.

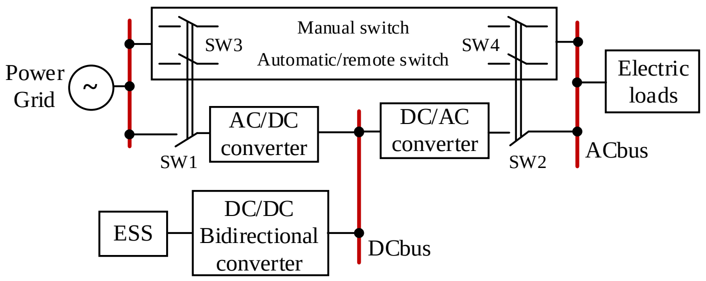

Fig. 20 Proposing bypass switches in UPSs to avoid external faults

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To operate above propose, SW1 and SW2 switches will be worked in interlock control witch SW3 and SW4 switches corresponding to automatic/manual mode to cut power converters out of both their input and output terminals. In this bypass operation, all power converters in UPSs doesn't work as represented in Fig. 21.

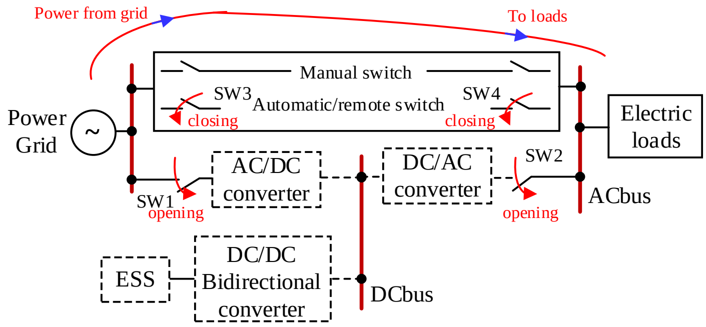

Fig. 21 Bypass operation in UPS

Using Newton-Raphson và ETAP software to simulate E13 grid in case of using two UPSs connected in parallel (A9 and A10), simulation result is represented in Fig. 22. Parameters of the UPSs are: rated power 400 kVA; cosφ=0.95. In Fig. 22, parameters of cables from UPSs to Bus B2 are: type XLPE 185 mm^2; 12m length. It must be emphasized that these cables have the same parameters and UPSs work together to meet power for loads. It means that CabB1-B2 cable are designed to reserve for UPSs and it only works if UPSs have failure.

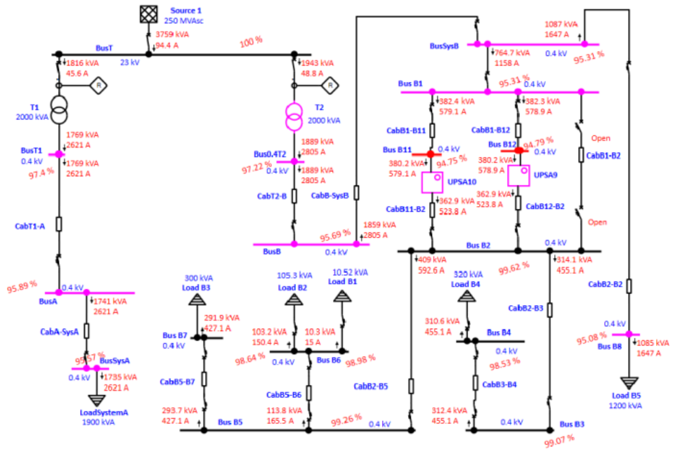

Fig. 22 Simulation result in case of using two UPSs and the same parameters for cables from UPSs to Bus B2

Using loss report function in ETAP software, the branch losses summary report in this operating mode is shown in TABLE VIII. It showed the power loss is 101.3+275 kVAr.

Table 8: Branch losses report in the mode using UPSs and the same parameters for cable from UPSs to bus B2

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
CabA-SysA	1.653	0.546	-1.649	-0.542	4.7	4.4	95.9	95.6	0.32
CabB11-B2	-0.343	-0.114	0.344	0.115	1.2	0.7	99.6	100.0	0.38
CabB12-B2	-0.343	-0.114	0.344	0.115	1.2	0.7	99.6	100.0	0.38
CabB1-B11	0.364	0.116	-0.363	-0.115	2.0	1.2	95.3	94.8	0.56
CabB1-B12	0.364	0.116	-0.363	-0.115	1.8	1.1	95.3	94.8	0.52
CabB2-B2	-1.031	-0.338	1.033	0.341	2.0	2.3	95.1	95.3	0.23
CabB2-B3	0.298	0.099	-0.297	-0.098	1.5	0.9	99.6	99.1	0.55
CabB2-B5	0.388	0.129	-0.387	-0.128	1.2	1.1	99.6	99.3	0.36
CabB3-B4	0.297	0.098	-0.295	-0.097	1.5	0.9	99.1	98.5	0.55
CabB5-B6	0.108	0.036	-0.108	-0.035	0.3	0.2	99.3	99.0	0.28
CabB5-B7	0.279	0.092	-0.277	-0.091	1.6	1.0	99.3	98.6	0.62
CabB-SysB	1.767	0.578	-1.761	-0.572	6.0	5.6	95.7	95.3	0.38
CabT1-A	-1.653	-0.546	1.675	0.567	22.0	20.5	95.9	97.4	1.51
CabT2-B	1.791	0.600	-1.767	-0.578	24.0	22.3	97.2	95.7	1.53
T1	1.689	0.666	-1.675	-0.567	14.1	98.9	100.0	97.4	2.60
T2	-1.791	-0.600	1.808	0.713	16.1	113.3	97.2	100.0	2.78
					101.3	275.0			

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If the length of cables from UPSs to Bus B2 is different (CabB11-B2 cable is 12m and CBB12-B2 cable is 18m), simulation result is represented in Fig. 23.

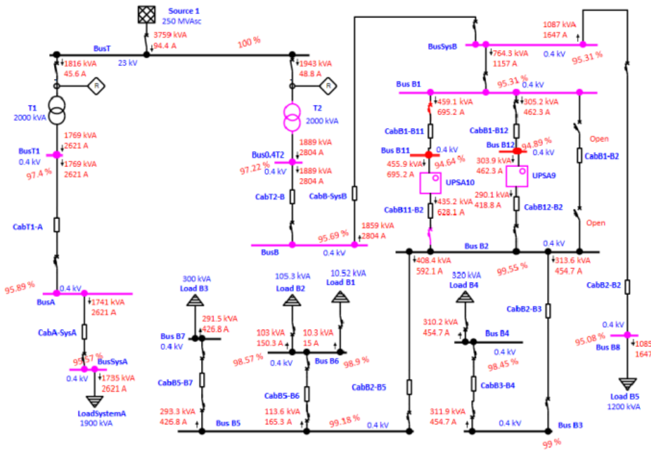

Fig. 23 Simulation result in case of using two UPSs and the different parameters for cables from UPSs to Bus B2

Using loss report function in ETAP software, the branch losses summary report in this operating mode is shown in TABLE IX. It showed the power loss is 101.9+275.4 kVAr.

Table 9: Branch losses report in the mode using UPS and the different lenght for cable from ups to bus b2

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
	MW	Mvar	MW	Mvar	kW	kvar	From	To	
CabA-SysA	1.653	0.546	-1.649	-0.542	4.7	4.4	95.9	95.6	0.32
CabB11-B2	-0.411	-0.136	0.413	0.137	1.7	1.0	99.5	100.0	0.45
CabB12-B2	-0.274	-0.091	0.275	0.092	1.2	0.7	99.5	100.0	0.45
CabB1-B11	0.437	0.139	-0.435	-0.137	2.8	1.7	95.3	94.6	0.67
CabB1-B12	0.291	0.092	-0.290	-0.092	1.2	0.7	95.3	94.9	0.42
CabB2-B2	-1.031	-0.338	1.033	0.341	2.0	2.3	95.1	95.3	0.23
CabB2-B3	0.298	0.099	-0.296	-0.098	1.5	0.9	99.5	99.0	0.55
CabB2-B5	0.388	0.129	-0.386	-0.128	1.2	1.1	99.5	99.2	0.36
CabB3-B4	0.296	0.098	-0.295	-0.097	1.5	0.9	99.0	98.5	0.55
CabB5-B6	0.108	0.036	-0.108	-0.035	0.3	0.2	99.2	98.9	0.28
CabB5-B7	0.278	0.092	-0.277	-0.091	1.6	1.0	99.2	98.6	0.62
CabB-SysB	1.767	0.578	-1.761	-0.572	6.0	5.6	95.7	95.3	0.38
CabT1-A	-1.653	-0.546	1.675	0.567	22.0	20.5	95.9	97.4	1.51
CabT2-B	1.791	0.600	-1.767	-0.578	24.0	22.3	97.2	95.7	1.53
T1	1.689	0.666	-1.675	-0.567	14.1	98.9	100.0	97.4	2.60
T2	-1.791	-0.600	1.807	0.713	16.1	113.2	97.2	100.0	2.78
					101.9	275.4			

CONCLUSIONS

This paper proposed three solutions to improve voltage quality and continuous power supply. These solutions help to overcome problems of losing power grid or cables caused by faults in power circuit. Moreover, this paper also proposed the designing structure and operating UPSs to ensure the reliability and safety for them. Newton-Raphson và ETAP software were used in this paper to study many operating modes for proposed E13 grid.

Simulation results showed that voltage tap changer in distribution power transformers helped to improve voltage quality for electric loads. However, it's difficult to apply this solution because all electric loads must be cut off before change voltage tap. Reserved generator can help to replace T2 transformer, reduce power losses and improve voltage quality. However, this solution makes high investment, high operating cost and affects much to the environment because it use fossil fuel to generate power. So, reserved generator only uses in case of having failure of transformers. For UPS solution, voltage quality can be fully improved (values of all buses in the substation were near nominal value). In case of using UPS, power losses in whole grid are higher than without using UPS due to power losses in themselves and power losses in branches corresponding to the increase of voltage buses. In real implementation, the length of cables from UPSs to load bus is often different. Simulation result in Fig. 23 showed power flow through UPSA10 was 455.9 kVA and made UPSA10 overload; power flow through UPSA9 was 303.9 kVA and made UPSA9 underload. The impedance difference causes the different power flows through UPSs in this simulation result. To avoid this problem, it must be designed the same impedance transmission by using the same parameters for both cables or internal impedance in UPSs to adjust power flows. In case of having fault in a UPS, both two UPSs must be cut off and the reserved cable must be switched on to supply power for loads.

The contribution of this paper can be applied to design and operate distribution power substations. Proposed solutions must be studied more deeply and individually to be suitable to many devices in the substation. In the future research, control method to regulate switching process will make clear to improve continuous power supply for electric loads.

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REFERENCES

1. Jiansheng Huang, Zhuhan Jiang, (2017), “Power Quality Assessment of Different Load Categories”, 4th International Conference on Power and Energy Systems Engineering, CPESE 2017, 25-29, Elsevier.
2. Daniel Ogheneovo Johnson, Kabiru Alani Hassan (2016), "Issues of Power Quality in Electrical Systems", International Journal of Energy and Power Engineering, 5(4), pp: 148-154, ISSN: 2326-960X (Online).
3. Ministry of Industry and Trade, Vietnam, "Circular 39/2015/TT-BCT".
4. Muhammad Yudha Rofandy, Arnawan Hasibuan, Rosdiana, (2022), “Analysis of the Effect of Bank Capacitor Placement as Voltage Drop Increase in Distribution Network”, Andalasian International Journal of Applied Science, Engineering and Technology, Vol. 02, No. 01, e-ISSN: 2797-0442.
5. Oscar Danilo Montoya, Francisco David Moya and Arul Rajagopalan (2022), “Annual Operating Costs Minimization in Electrical Distribution Networks via the Optimal Selection and Location of Fixed-Step Capacitor Banks Using a Hybrid Mathematical Formulation”, Mathematics, Vol. 10, 1600.
6. Okelola, M. O (2018), Application of Auto-Switched Capacitor Bank to Mitigate Voltage Collapse Problem in Distribution System; a Case Study of Osogbo South –Western, Nigeria", International Journal of Scientific Research and Management (IJSRM), ISSN (e): 2321-3418, Vol. 06, Issue. 07.
7. Manuel S. Alvarez-Alvarado, Carlos D. Rodríguez-Gallegos, Dilan Jayaweera (2017), "Optimal planning and operation of static VAR compensators in a distribution system withnon-linear loads", IET Generation, Transmission & Distribution, Vol. 12 Iss. 15.
8. Sunil B. Sinare, Prasad D. Kulkarni (2019), "Implementation of Static VAR Compensator for Performance Improvement in Electrical Distribution System", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN (Online): 2278 – 8875, Vol. 8, Issue 9.
9. Aaron Don M. Africa, Juan Miguel C. Lacanilao, Ray Vincent Alin B. Lamdagan, "Effect of a Static Var Compensator on an Electrical Power Transmission System", International Journal of Emerging Trends in Engineering Research, ISSN 2347 - 3983, Volume 8. No. 9.
10. Narinder Singh, Ishan Thakur (2016), "A Review on Power Quality Improvement in Distribution System Using UPQC", International Research Journal of Engineering and Technology (IRJET), e-ISSN: 2395-0056, Volume 03, Issue 07.
11. Ngo Duc Minh, Le Tien Phong (2019), "Effect of Transformer Parameters and Line Reactor on Power Flows in High-Voltage Systems", American Journal of Electrical Power and Energy Systems, 8(3), pp: 77-85, ISSN: 2326-9200 (Online).
12. Vilas S. Bugade , Ekta Mishra , Mahesh H Jayebhaye3, Hemlata Joshi, Akshay Patil, Baliram Kale (2018), "Automatic Voltage Control of Load using on Load Tap Changer", International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887 Volume 6 Issue III.
13. Kwang-Hoon Yoon, Joong-Woo Shin, Tea-Yang Nam, Jae-Chul Kim, WWond-Sik Moon (2022), “Operation Method of On-Load Tap Changer on Main Transformer Considering Reverse Power Flow in

Distribution System Connected with High Penetration on Photovoltaic System", Energies 2022, 15(17), 6473.

14. Bakhtyar Hoseinzadeh, Frede Blaabjerg (2022), "A novel control technique for on-load tap changer to enlarge thereactive power capability of wind power plants", IET Generation, Transmission & Distribution, 16, 2928–2938.
15. Hicham Fakham, Di Lu, Bruno Francois, (2011), "Power Control Design of a Battery Charger in a Hybrid Active PV Generator for load-Following Applications", IEEE Transaction on Industrial Electronics, Vol. 58, Issue. 1, pp. 85-94.
16. Cecilia P. Abaricia (2021), "Development of Uninterruptible Power Supply (UPS) with Power Saving Features", International Journal of Computing Sciences Research, Vol. 7, pp: 1109-1124, ISSN online: 2546-115X.
17. Mahantesh Mattada, Saba Fatima, V Viswanatha, Kalyani Rasika, P. Vishwanath (2022), "Smart Power Management System for Uninterupted Power Supplies (UPS), with Priorites", Global Transitions Proceedings 3, pp: 38-42.
18. Goufu Liu, Ximu Liu and Weiwei Wang (2020), "Research on the Control Method of UPS Inverter Circuit Considering Additional Filtering Branch", International Conference on Electrical Automation and Mechanical Engineering, Journal of Physics: Conference Series, IOP Publishing,1626(2020).
19. V.G. Neve, Vaishnavi Meshram, Dinesh Shevatakar, Prashant Chavhan, Nikita Kottewar, Avan Pawar, Shivam Neware, Khaushal Talkokulwar (2023), "Research Paper on Uninterrupted Power Supply (UPS) by Using Solar", International Research Journal of Modernization in Engineering Technology and Science, Volume: 05, Issue: 05, e-ISSN: 2582-5208.
20. Aashwin Prasad (2022), "Analysis of Software Tools Used for Load-Flow Studies", 4th International Conference on Advances in Computing, Communication Control and Networking (ICAC3N), ISBN: 978-1-6654-7436-8.
21. Sourav Mallick, D.V. Rajan, S.S. Thakur, P. Achrjee, S.P. Ghoshal (2011), "Devlopment of a New Algorithm for Power Flow Analysis", International Journal of Electrical Power and Energy Systems, Elsevier, Vol. 33, Issue 8.
22. Mohammadjavad Mobarra, Miloud Rezkallah, and Adrian Ilinca (2022), "Vaviable Speed Diesel Generators: Performance and Characteristic Comparison", energies, 15, 592