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Determination of Loading Margin of Nigerian 330kV Transmission Network Using Continuation Power Flow Method

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ABSTRACT: Continuation power flow method was applied in the modelling of the Nigerian 330kV transmission network in Electrical Transient Analyzer Program (ETAP) 12.6 software to establish the loading margin. From the continuation power flow report, it was concluded that a loading margin of 55.785MW was established corresponding to a loading factor of 0.18p.u and maximum loading demand of 3519.653MW. The continuation power flow failed to run beyond 0.18p.u loading factor which implies voltage collapse.

KEYWORDS: Continuation Power Flow, Loading Margin, Generator Bus, Load Bus, Loading Factor, Loading Parameter.

I. INTRODUCTION

Power output from Nigeria's generating companies (GenCos) dropped leading to consumption of 3,014.8 megawatts on 19th August, 2019 from a monthly average of 3,578MW with a loading margin of about 56MW in August maintaining an available generation capacity of 4,000MW latest data has shown [1]. 3014.8MW has been maintained over time representing about 75.37% loading to avoid imminent voltage collapse owing to the feeling that the network has a weak loading margin [1]. The assumption here is that there has been a weak loading margin since no new load was encouraged in the system to avoid voltage collapse.
For a particular operating point, the amount of additional load allowable before the occurrence of voltage collapse is called loading margin. It is therefore pertinent to establish the exact loading margin of the Nigerian 330kV transmission network.

II. RELATED WORKS

In power system, maximum loading point is essential to be known in advance so that proper control action can be taken in order to avoid the occurrence of voltage collapse [2].Whenever the voltage of a given bus in the transmission system dips below the rated voltage value, all substations and equipment tied to that bus run at reduced efficiency and damages may suffice [3].The use of Continuation Power Flow (CPF) method allows maximum loading limits and the value of critical voltage on each bus in the power system to be known [4]. The goal of CPF is to trace the buses voltage profiles from a known initial solution which is the base case and using a predictor-corrector scheme to find solutions after the maximum loading point. This entire process can be used to obtain voltage stability margin and additional information about the voltage behavior of the system buses with the incremental loading level [5].

One of the first techniques used to determine the maximum loading condition of a power system is the continuation power flow [6]. This technique consists in computing a series of power flows while increasing the overall loading level of the system. Load margin analysis has been profoundly identified as one of the fundamental measurement voltage stability studies. In load margin assessment, voltage collapse point is identified by increasing the load beyond the maximum loading point where subsequently the system starts to lose its equilibrium. With CPF therefore, weakest bus identification can be done devoid of excessive calculation [7]. In CPF, power flow starts with the initial operating point and increases load to the maximum loading point [8].

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Continuation power flow overcomes the problem of singularity at the voltage stability limit as it finds successive load flow solutions according to a load scenario [9]. According to Shadangi & Soni [9], the CPF method is more accurate and simpler for voltage stability analysis. Continuation power flow analysis is based on locally parametrized continuation method which intends to avoid the singularity of the Jacobian by slightly reformulating the power flow equations [10]. The Continuous Power Flow (CPF) method is the best for on-line application as it is accurate, reliable and moderately fast. The reliability is since it does not have serious convergence issues arising from device limits [11].

III. MATERIALS AND METHOD

Various research materials which include basic parameters such as transmission route length, impedance, transmission lines power rating, generators active power, bus data, power factor, transformers rating, base load, etc required to determine the loading margin of the Nigerian 330kV transmission network were collected from the National Control Centre (NCC) while others were computed to aid the enhancement. Continuation Power Flow method was used to obtain the loading margin of the Nigerian 330kV transmission network as the data with respect to this served as input data in ETAP 12.6 software.

Considering the equation

$P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ when load parameter λ was 1 with a loading factor of 0.02p.u, then, for 1st load increase

Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.02X182)$, $P_{Di} = 185.64MW$

Jebba Bus has $P_{Di} = 15.5 + 1(0.02\ X\ 15.5)$, $P_{Di} = 15.81MW$

Osogbo Bus has $P_{Di} = 174 + 1(0.02\ X\ 174)$, $P_{Di} = 177.48MW$

Ayede Bus has $P_{Di} = 274 + 1(0.02\ X\ 274)$, $P_{Di} = 279.48MW$

Ikeja-West has $P_{Di} = 375.08 + 1(0.02\ X\ 375.08)$, $P_{Di} = 382.58MW$

Akamgba Bus has $P_{Di} = 312 + 1(0.02\ X\ 312)$, $P_{Di} = 318.24MW$

Aja Bus has $P_{Di} = 80 + 1(0.02\ X\ 80)$, $P_{Di} = 81.60MW$

Benin Bus has $P_{Di} = 74 + 1(0.02\ X\ 74)$, $P_{Di} = 75.48MW$

Ajaokuta Bus has $P_{Di} = 51 + 1(0.02\ X\ 51)$, $P_{Di} = 52.02MW$

Aladja Bus has $P_{Di} = 56 + 1(0.02\ X\ 56)$, $P_{Di} = 57.12MW$

Onitsha Bus has $P_{Di} = 139 + 1(0.02\ X\ 139)$, $P_{Di} = 141.78MW$

New-Haven Bus has $P_{Di} = 121 + 1(0.02\ X\ 121)$, $P_{Di} = 123.42MW$

Alaoji Bus has $P_{Di} = 220 + 1(0.02\ X\ 220)$, $P_{Di} = 224.40MW$

Katampe Bus has $P_{Di} = 234.50 + 1(0.02\ X\ 234.50)$, $P_{Di} = 239.19MW$

Kaduna Bus has $P_{Di} = 212 + 1(0.02\ X\ 212)$, $P_{Di} = 216.24MW$

Kano Bus has $P_{Di} = 231 + 1(0.02\ X\ 231)$, $P_{Di} = 235.62MW$

Jos Bus has $P_{Di} = 81 + 1(0.02\ X\ 81)$, $P_{Di} = 82.62MW$

Gombe Bus has $P_{Di} = 112 + 1(0.02\ X\ 112)$, $P_{Di} = 114.24MW$

Yola Bus has $P_{Di} = 70 + 1(0.02\ X\ 70)$, $P_{Di} = 71.40MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.04p.u, then, for 2nd load increase

Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.04\ X\ 182)$, $P_{Di} = 189.28MW$

Jebba Bus has $P_{Di} = 15.5 + 1(0.04\ X\ 15.5)$, $P_{Di} = 16.12MW$

Osogbo Bus has $P_{Di} = 174 + 1(0.04\ X\ 174)$, $P_{Di} = 180.96MW$

Ayede Bus has $P_{Di} = 274 + 1(0.04\ X\ 274)$, $P_{Di} = 284.96MW$

Ikeja-West has $P_{Di} = 375.08 + 1(0.04\ X\ 375.08)$, $P_{Di} = 390.08MW$

Akamgba Bus has $P_{Di} = 312 + 1(0.04\ X\ 312)$, $P_{Di} = 324.48MW$

Aja Bus has $P_{Di} = 80 + 1(0.04\ X\ 80)$, $P_{Di} = 83.20MW$

Benin Bus has $P_{Di} = 74 + 1(0.04\ X\ 74)$, $P_{Di} = 76.96MW$

Ajaokuta Bus has $P_{Di} = 51 + 1(0.04\ X\ 51)$, $P_{Di} = 53.04MW$

Aladja Bus has $P_{Di} = 56 + 1(0.04\ X\ 56)$, $P_{Di} = 58.24MW$

Onitsha Bus has $P_{Di} = 139 + 1(0.04\ X\ 139)$, $P_{Di} = 144.56MW$

New-Haven Bus has $P_{Di} = 121 + 1(0.04\ X\ 121)$, $P_{Di} = 125.84MW$

Alaoji Bus has $P_{Di} = 220 + 1(0.04\ X\ 220)$, $P_{Di} = 228.80MW$

Katampe Bus has $P_{Di} = 234.50 + 1(0.04\ X\ 234.50)$, $P_{Di} = 243.88MW$

Kaduna Bus has $P_{Di} = 212 + 1(0.04\ X\ 212)$, $P_{Di} = 220.48MW$

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Kano Bus has $P_{Di} = 231 + 1(0.04 X 231)$, $P_{Di} = 240.24MW$
Jos Bus has $P_{Di} = 81 + 1(0.04 X 81)$, $P_{Di} = 84.24MW$
Gombe Bus has $P_{Di} = 112 + 1(0.04 X 112)$, $P_{Di} = 116.48MW$
Yola Bus has $P_{Di} = 70 + 1(0.04 X 70)$, $P_{Di} = 72.80MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.06p.u, then, for 3rd load increase
Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.06 X 182)$, $P_{Di} = 192..92MW$
Jebba Bus has $P_{Di} = 15.5 + 1(0.06 X 15.5)$, $P_{Di} = 16.443MW$
Osogbo Bus has $P_{Di} = 174 + 1(0.06 X 174)$, $P_{Di} = 184.44MW$
Ayede Bus has $P_{Di} = 274 + 1(0.06 X 274)$, $P_{Di} = 290.44MW$
Ikeja-West has $P_{Di} = 375.08 + 1(0.06 X 375.08)$, $P_{Di} = 397.85MW$
Akamgba Bus has $P_{Di} = 312 + 1(0.06 X 312)$, $P_{Di} = 330.72MW$
Aja Bus has $P_{Di} = 80 + 1(0.06 X 80)$, $P_{Di} = 84.80MW$
Benin Bus has $P_{Di} = 74 + 1(0.06 X 74)$, $P_{Di} = 78.44MW$
Ajaokuta Bus has $P_{Di} = 51 + 1(0.06 X 51)$, $P_{Di} = 54.06MW$
Aladja Bus has $P_{Di} = 56 + 1(0.06 X 56)$, $P_{Di} = 59.36MW$
Onitsha Bus has $P_{Di} = 139 + 1(0.06 X 139)$, $P_{Di} = 147.34MW$
New-Haven Bus has $P_{Di} = 121 + 1(0.06 X 121)$, $P_{Di} = 128.26MW$
Alaoji Bus has $P_{Di} = 220 + 1(0.06 X 220)$, $P_{Di} = 233.20MW$
Katampe Bus has $P_{Di} = 234.50 + 1(0.06 X 234.50)$, $P_{Di} = 248.57MW$
Kaduna Bus has $P_{Di} = 212 + 1(0.06 X 212)$, $P_{Di} = 224.72MW$
Kano Bus has$P_{Di} = 231 + 1(0.06 X 231)$, $P_{Di} = 244.86MW$
Jos Bus has $P_{Di} = 81 + 1(0.06 X 81)$, $P_{Di} = 85.86MW$
Gombe Bus has $P_{Di} = 112 + 1(0.06 X 112)$, $P_{Di} = 118.72MW$
Yola Bus has $P_{Di} = 70 + 1(0.06 X 70)$, $P_{Di} = 74.40MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.08p.u, then, for 4th load increase
Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.08 X 182)$, $P_{Di} = 196.56MW$
Jebba Bus has $P_{Di} = 15.5 + 1(0.08 X 15.5)$, $P_{Di} = 16.74MW$
Osogbo Bus has $P_{Di} = 174 + 1(0.08 X 174)$, $P_{Di} = 187.92MW$
Ayede Bus has $P_{Di} = 274 + 1(0.08 X 274)$, $P_{Di} = 295.92MW$
Ikeja-West has $P_{Di} = 375.08 + 1(0.08 X 375.08)$, $P_{Di} = 405.09MW$
Akamgba Bus has $P_{Di} = 312 + 1(0.08 X 312)$, $P_{Di} = 336.96MW$
Aja Bus has $P_{Di} = 80 + 1(0.08 X 80)$, $P_{Di} = 86.40MW$
Benin Bus has $P_{Di} = 74 + 1(0.08 X 74)$, $P_{Di} = 79.92MW$
Ajaokuta Bus has $P_{Di} = 51 + 1(0.08 X 51)$, $P_{Di} = 55.08MW$
Aladja Bus has $P_{Di} = 56 + 1(0.08 X 56)$, $P_{Di} = 60.48MW$
Onitsha Bus has $P_{Di} = 139 + 1(0.08 X 139)$, $P_{Di} = 150.12MW$
New-Haven Bus has $P_{Di} = 121 + 1(0.08 X 121)$, $P_{Di} = 130.68MW$
Alaoji Bus has $P_{Di} = 220 + 1(0.08 X 220)$, $P_{Di} = 237.60MW$
Katampe Bus has $P_{Di} = 234.50 + 1(0.08 X 234.50)$, $P_{Di} = 257.26MW$
Kaduna Bus has $P_{Di} = 212 + 1(0.08 X 212)$, $P_{Di} = 228.96MW$
Kano Bus has $P_{Di} = 231 + 1(0.08 X 231)$, $P_{Di} = 249.48MW$
Jos Bus has $P_{Di} = 81 + 1(0.08 X 81)$, $P_{Di} = 87.48MW$
Gombe Bus has $P_{Di} = 112 + 1(0.08 X 112)$, $P_{Di} = 120.96MW$
Yola Bus has $P_{Di} = 70 + 1(0.08 X 70)$, $P_{Di} = 75.60MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.10p.u, then, for 5th load increase
Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.10 X 182)$, $P_{Di} = 200.20MW$
Jebba Bus has $P_{Di} = 15.5 + 1(0.10 X 15.5)$, $P_{Di} = 17.05MW$
Osogbo Bus has $P_{Di} = 174 + 1(0.10 X 174)$, $P_{Di} = 191.40MW$
Ayede Bus has $P_{Di} = 274 + 1(0.10 X 274)$, $P_{Di} = 301.40MW$
Ikeja-West has $P_{Di} = 375.08 + 1(0.10 X 375.08)$, $P_{Di} = 412.59MW$
Akamgba Bus has $P_{Di} = 312 + 1(0.10 X 312)$, $P_{Di} = 343.20MW$

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Aja Bus has $P_{Di} = 80 + 1(0.10\,X\ 80)$, $P_{Di} = 88.00MW$
Benin Bus has $P_{Di} = 74 + 1(0.10\,X\,74)$, $P_{Di} = 81.40MW$
Ajaokuta Bus has $P_{Di} = 51 + 1(0.10\,X\,51)$, $P_{Di} = 56.10MW$
Aladja Bus has $P_{Di} = 56 + 1(0.10\,X\ 56)$, $P_{Di} = 61.60MW$
Onitsha Bus has $P_{Di} = 139 + 1(0.10\,X\,139)$, $P_{Di} = 152.90MW$
New-Haven Bus has $P_{Di} = 121 + 1(0.10\,X\,121)$, $P_{Di} = 133.10MW$
Alaoji Bus has $P_{Di} = 220 + 1(0.10\,X\,220)$, $P_{Di} = 242.00MW$
Katampe Bus has $P_{Di} = 234.50 + 1(0.10\,X\ 234.50)$, $P_{Di} = 257.95MW$
Kaduna Bus has $P_{Di} = 212 + 1(0.10\,X\,212)$, $P_{Di} = 233.20MW$
Kano Bus has $P_{Di} = 231 + 1(0.10\,X\ 231)$, $P_{Di} = 254.10MW$
Jos Bus has $P_{Di} = 81 + 1(0.10\,X\ 81)$, $P_{Di} = 89.10MW$
Gombe Bus has $P_{Di} = 112 + 1(0.10\,X\ 112)$, $P_{Di} = 123.20MW$
Yola Bus has $P_{Di} = 70 + 1(0.10\,X\ 70)$, $P_{Di} = 77.00MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.12p.u, then, for 6th load increase
Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.12\,X\,182)$, $P_{Di} = 203.84MW$
Jebba Bus has $P_{Di} = 15.5 + 1(0.12\,X\ 15.5)$, $P_{Di} = 17.36MW$
Osogbo Bus has $P_{Di} = 174 + 1(0.12\,X\ 174)$, $P_{Di} = 194.88MW$
Ayede Bus has $P_{Di} = 274 + 1(0.12\,X\ 274)$, $P_{Di} = 306.88MW$
Ikeja-West has $P_{Di} = 375.08 + 1(0.12\,X\,375.08)$, $P_{Di} = 420.09MW$
Akamgba Bus has $P_{Di} = 312 + 1(0.12\,X\,312)$, $P_{Di} = 349.44MW$
Aja Bus has $P_{Di} = 80 + 1(0.12\,X\,80)$, $P_{Di} = 89.60MW$
Benin Bus has $P_{Di} = 74 + 1(0.12\,X\ 74)$, $P_{Di} = 82.88MW$
Ajaokuta Bus has $P_{Di} = 51 + 1(0.12\,X\,51)$, $P_{Di} = 57.12MW$
Aladja Bus has $P_{Di} = 56 + 1(0.12\,X\ 56)$, $P_{Di} = 62.72MW$
Onitsha Bus has $P_{Di} = 139 + 1(0.12\,X\,139)$, $P_{Di} = 155.68MW$
New-Haven Bus has $P_{Di} = 121 + 1(0.12\,X\,121)$, $P_{Di} = 135.52MW$
Alaoji Bus has $P_{Di} = 220 + 1(0.12\,X\,220)$, $P_{Di} = 246.40MW$
Katampe Bus has $P_{Di} = 234.50 + 1(0.12\,X\ 234.50)$, $P_{Di} = 262.64MW$
Kaduna Bus has $P_{Di} = 212 + 1(0.12\,X\,212)$, $P_{Di} = 237.44MW$
Kano Bus has $P_{Di} = 231 + 1(0.12\,X\ 231)$, $P_{Di} = 258.72MW$
Jos Bus has $P_{Di} = 81 + 1(0.12\,X\ 81)$, $P_{Di} = 90.72MW$
Gombe Bus has $P_{Di} = 112 + 1(0.12\,X\ 112)$, $P_{Di} = 125.44MW$
Yola Bus has $P_{Di} = 70 + 1(0.12\,X\,70)$, $P_{Di} = 78.40MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.14p.u, then, for 7th load increase
Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.14\,X\ 182)$, $P_{Di} = 207.48MW$
Jebba Bus has $P_{Di} = 15.5 + 1(0.14\,X\ 15.5)$, $P_{Di} = 17.67MW$
Osogbo Bus has $P_{Di} = 174 + 1(0.14\,X\,174)$, $P_{Di} = 198.36MW$
Ayede Bus has $P_{Di} = 274 + 1(0.14\,X\ 274)$, $P_{Di} = 312.36MW$
Ikeja-West has $P_{Di} = 375.08 + 1(0.14\,X\,375.08)$, $P_{Di} = 427.59MW$
Akamgba Bus has $P_{Di} = 312 + 1(0.14\,X\ 312)$, $P_{Di} = 355.68MW$
Aja Bus has $P_{Di} = 80 + 1(0.14\,X\ 80)$, $P_{Di} = 91.20MW$
Benin Bus has $P_{Di} = 74 + 1(0.14\,X\ 74)$, $P_{Di} = 84.36MW$
Ajaokuta Bus has $P_{Di} = 51 + 1(0.14\,X\,51)$, $P_{Di} = 58.14MW$
Aladja Bus has $P_{Di} = 56 + 1(0.14\,X\ 56)$, $P_{Di} = 63.84MW$
Onitsha Bus has $P_{Di} = 139 + 1(0.14\,X\,139)$, $P_{Di} = 158.46MW$
New-Haven Bus has $P_{Di} = 121 + 1(0.14\,X\,121)$, $P_{Di} = 137.74MW$
Alaoji Bus has $P_{Di} = 220 + 1(0.14\,X\,220)$, $P_{Di} = 250.80MW$
Katampe Bus has $P_{Di} = 234.50 + 1(0.14\,X\,234.50)$, $P_{Di} = 267.33MW$
Kaduna Bus has $P_{Di} = 212 + 1(0.14\,X\,212)$, $P_{Di} = 241.68MW$
Kano Bus has $P_{Di} = 231 + 1(0.14\,X\ 231)$, $P_{Di} = 263.34MW$
Jos Bus has $P_{Di} = 81 + 1(0.14\,X\ 81)$, $P_{Di} = 92.34MW$
Gombe Bus has $P_{Di} = 112 + 1(0.14\,X\ 112)$, $P_{Di} = 127.68MW$

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Yola Bus has $P_{Di} = 70 + 1(0.14 X 70)$, $P_{Di} = 79.80MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.16p.u, then, for 8th load increase
Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.16 X 182)$, $P_{Di} = 211.12MW$
Jebba Bus has $P_{Di} = 15.5 + 1(0.16 X 15.5)$, $P_{Di} = 17.98MW$
Osogbo Bus has $P_{Di} = 174 + 1(0.16 X 174)$, $P_{Di} = 201.84MW$
Ayede Bus has $P_{Di} = 274 + 1(0.16 X 274)$, $P_{Di} = 317.84MW$
Ikeja-West has $P_{Di} = 375.08 + 1(0.16 X 375.08)$, $P_{Di} = 435.09MW$
Akamgba Bus has $P_{Di} = 312 + 1(0.16 X 312)$, $P_{Di} = 361.92MW$
Aja Bus has $P_{Di} = 80 + 1(0.16 X 80)$, $P_{Di} = 92.80MW$
Benin Bus has $P_{Di} = 74 + 1(0.16 X 74)$,$P_{Di} = 85.84MW$
Ajaokuta Bus has $P_{Di} = 51 + 1(0.16 X 51)$, $P_{Di} = 59.16MW$
Aladja Bus has $P_{Di} = 56 + 1(0.16 X 56)$, $P_{Di} = 64.96MW$
Onitsha Bus has $P_{Di} = 139 + 1(0.16 X 139)$, $P_{Di} = 161.24MW$
New-Haven Bus has $P_{Di} = 121 + 1(0.16 X 121)$, $P_{Di} = 140.36MW$
Alaoji Bus has$P_{Di} = 220 + 1(0.16 X 220)$, $P_{Di} = 255.20MW$
Katampe Bus has $P_{Di} = 234.50 + 1(0.16 X 234.50)$, $P_{Di} = 272.02MW$
Kaduna Bus has $P_{Di} = 212 + 1(0.16 X 212)$, $P_{Di} = 245.92MW$
Kano Bus has $P_{Di} = 231 + 1(0.16 X 231)$, $P_{Di} = 267.96MW$
Jos Bus has $P_{Di} = 81 + 1(0.16 X 81)$, $P_{Di} = 93.96MW$
Gombe Bus has $P_{Di} = 112 + 1(0.16 X 112)$, $P_{Di} = 129.92MW$
Yola Bus has $P_{Di} = 70 + 1(0.16 X 70)$, $P_{Di} = 81.20MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.18p.u, then, for 9th load increase
Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.18 X 182)$, $P_{Di} = 214.76MW$
Jebba Bus has $P_{Di} = 15.5 + 1(0.18 X 15.5)$, $P_{Di} = 18.29MW$
Osogbo Bus has $P_{Di} = 174 + 1(0.18 X 174)$, $P_{Di} = 205.32MW$
Ayede Bus has $P_{Di} = 274 + 1(0.18 X 274)$, $P_{Di} = 323.32MW$
Ikeja-West has $P_{Di} = 375.08 + 1(0.18 X 375.08)$, $P_{Di} = 442.59MW$
Akamgba Bus has $P_{Di} = 312 + 1(0.18 X 312)$, $P_{Di} = 368.16MW$
Aja Bus has $P_{Di} = 80 + 1(0.18 X 80)$, $P_{Di} = 94.40MW$
Benin Bus has $P_{Di} = 74 + 1(0.18 X 74)$, $P_{Di} = 87.32MW$
Ajaokuta Bus has $P_{Di} = 51 + 1(0.18 X 51)$, $P_{Di} = 60.18MW$
Aladja Bus has $P_{Di} = 56 + 1(0.18 X 56)$, $P_{Di} = 66.08MW$
Onitsha Bus has $P_{Di} = 139 + 1(0.18 X 139)$, $P_{Di} = 164.02MW$
New-Haven Bus has $P_{Di} = 121 + 1(0.18 X 121)$, $P_{Di} = 142.78MW$
Alaoji Bus has $P_{Di} = 220 + 1(0.18 X 220)$, $P_{Di} = 259.60MW$
Katampe Bus has $P_{Di} = 234.50 + 1(0.18 X 234.50)$, $P_{Di} = 276.71MW$
Kaduna Bus has $P_{Di} = 212 + 1(0.18 X 212)$, $P_{Di} = 250.16MW$
Kano Bus has $P_{Di} = 231 + 1(0.18 X 231)$, $P_{Di} = 272.58MW$
Jos Bus has $P_{Di} = 81 + 1(0.18 X 81)$, $P_{Di} = 95.58MW$
Gombe Bus has $P_{Di} = 112 + 1(0.18 X 112)$, $P_{Di} = 132.16MW$
Yola Bus has $P_{Di} = 70 + 1(0.18 X 70)$, $P_{Di} = 82.60MW$

From $P_{Di} = P_{Dio} + \lambda(P_{\Delta base})$ with a loading factor of 0.20p.u, then, for 10th load increase
Birnin Kebbi Bus has $P_{Di} = 182 + 1(0.20 X 182)$, $P_{Di} = 218.40MW$
Jebba Bus has $P_{Di} = 15.5 + 1(0.20 X 15.5)$, $P_{Di} = 18.60MW$
Osogbo Bus has $P_{Di} = 174 + 1(0.20 X 174)$, $P_{Di} = 208.80MW$
Ayede Bus has $P_{Di} = 274 + 1(0.20 X 274)$, $P_{Di} = 328.80MW$
Ikeja-West has $P_{Di} = 375.08 + 1(0.20 X 375.08)$, $P_{Di} = 450.10MW$
Akamgba Bus has $P_{Di} = 312 + 1(0.20 X 312)$, $P_{Di} = 374.40MW$
Aja Bus has $P_{Di} = 80 + 1(0.20 X 80)$, $P_{Di} = 96.00MW$
Benin Bus has $P_{Di} = 74 + 1(0.20 X 74)$, $P_{Di} = 88.80MW$
Ajaokuta Bus has $P_{Di} = 51 + 1(0.20 X 51)$, $P_{Di} = 61.20MW$

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Aladja Bus has $P_{Di} = 56 + 1(0.20\ X\ 56)$, $P_{Di} = 67.20MW$
Onitsha Bus has $P_{Di} = 139 + 1(0.20\ X\ 139)$, $P_{Di} = 166.80MW$
New-Haven Bus has $P_{Di} = 121 + 1(0.20\ X\ 121)$, $P_{Di} = 145.20MW$
Alaoji Bus has $P_{Di} = 220 + 1(0.20\ X\ 220)$, $P_{Di} = 264.00MW$
Katamkpe Bus has $P_{Di} = 234.50 + 1(0.20\ X\ 234.50)$, $P_{Di} = 281.40MW$
Kaduna Bus has $P_{Di} = 212 + 1(0.20\ X\ 212)$, $P_{Di} = 254.40MW$
Kano Bus has $P_{Di} = 231 + 1(0.20\ X\ 231)$, $P_{Di} = 277.20MW$
Jos Bus has $P_{Di} = 81 + 1(0.20\ X\ 81)$, $P_{Di} = 97.20MW$
Gombe Bus has $P_{Di} = 112 + 1(0.20\ X\ 112)$, $P_{Di} = 134.40MW$
Yola Bus has $P_{Di} = 70 + 1(0.20\ X\ 70)$, $P_{Di} = 84.00MW$

Upon getting all the data required to model and simulate to establish the loading margin of Nigerian 330kV transmission network with the use of ETAP 12.6 software, the data were used as input data and are shown in in the following way.

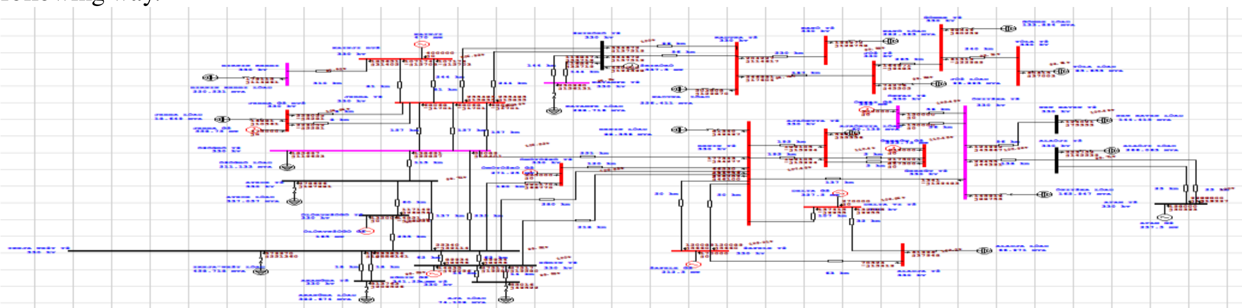

Fig. 1 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software (1st Load Increase at 0.02p.u)

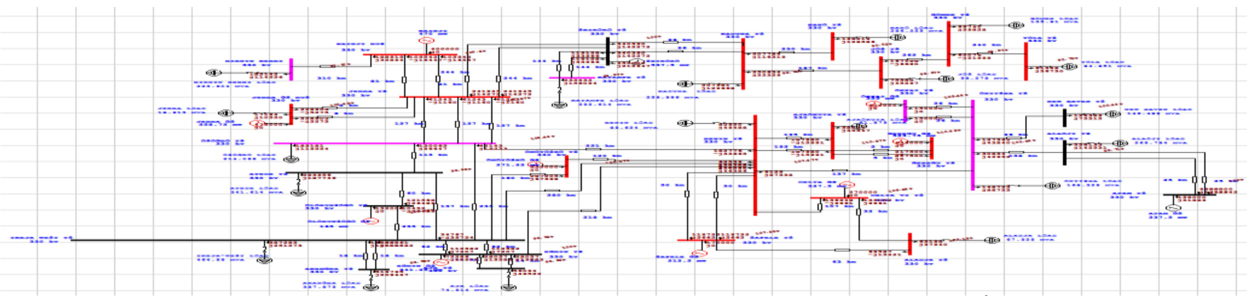

Fig. 2 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software (2nd Load Increase at 0.04p.u)

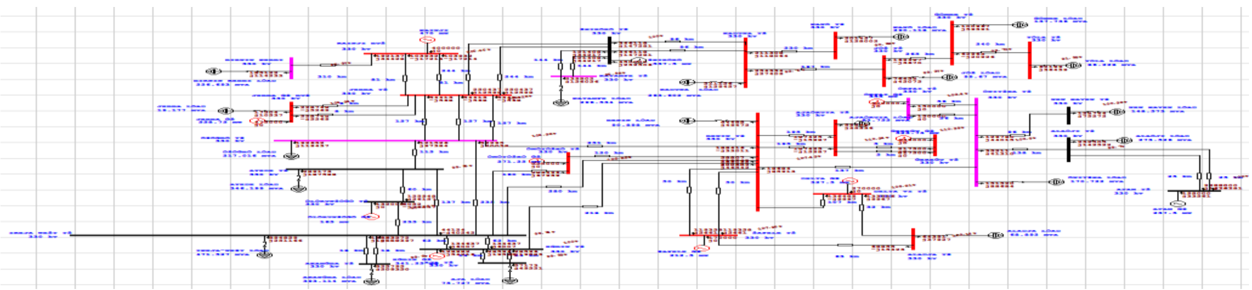

Fig. 3Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software (3rd Load Increase at 0.06p.u)

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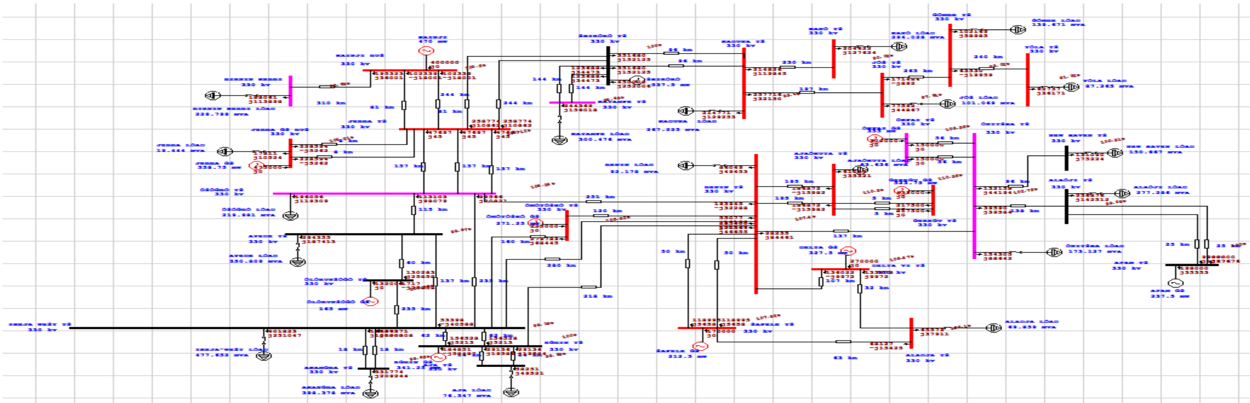

Fig. 4 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software (4th Load Increase at 08p.u)

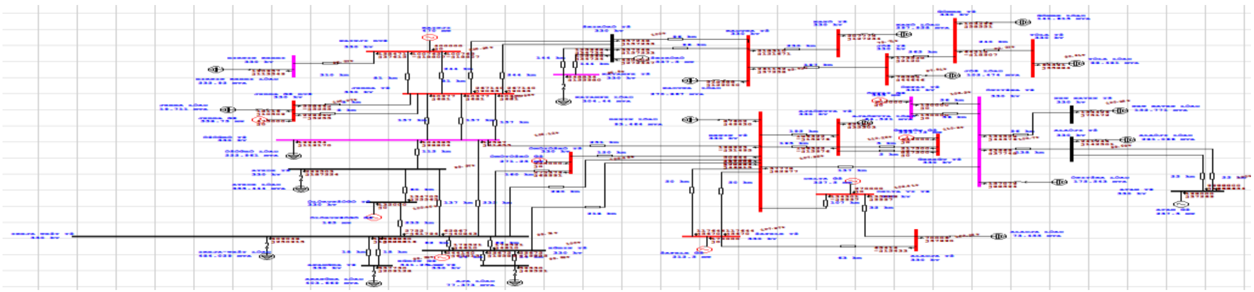

Fig. 5 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software (5th Load Increase at 0.10p.u)

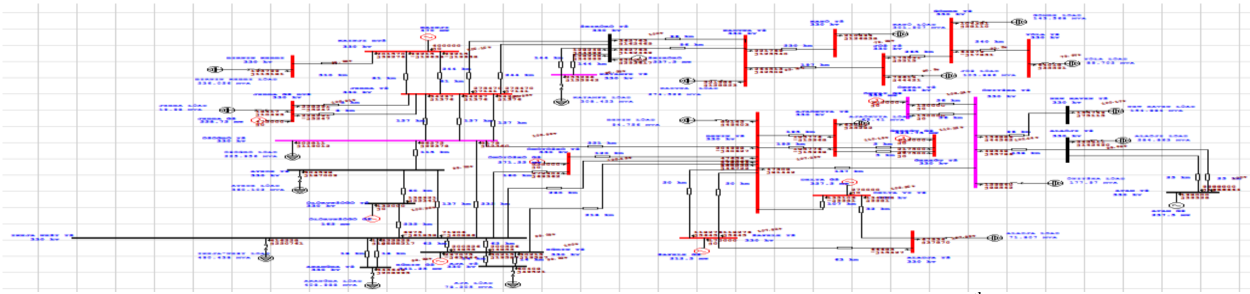

Fig. 6 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software (6th Load Increase at 0.12p.u)

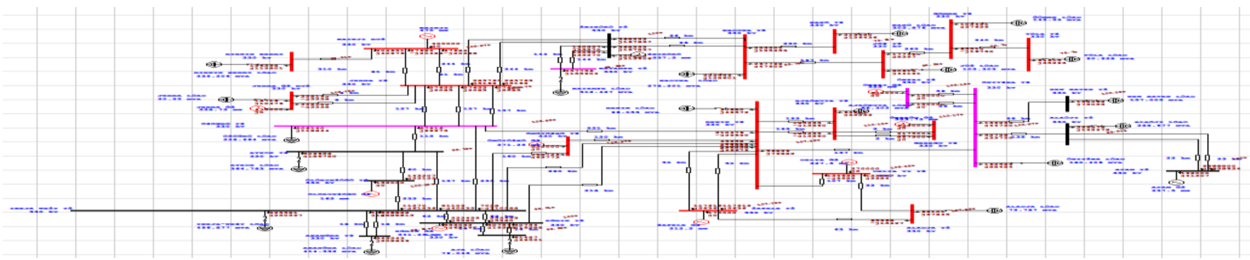

Fig. 7 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software(7th Load Increase at 0.14p.u)

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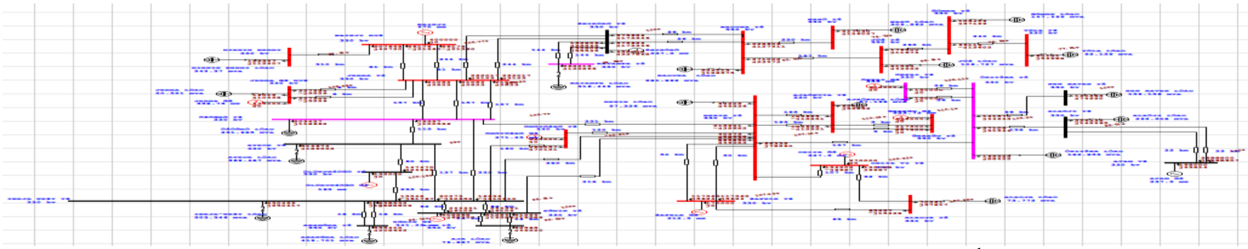

Fig. 8 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software (8th Load Increase at 0.16p.u)

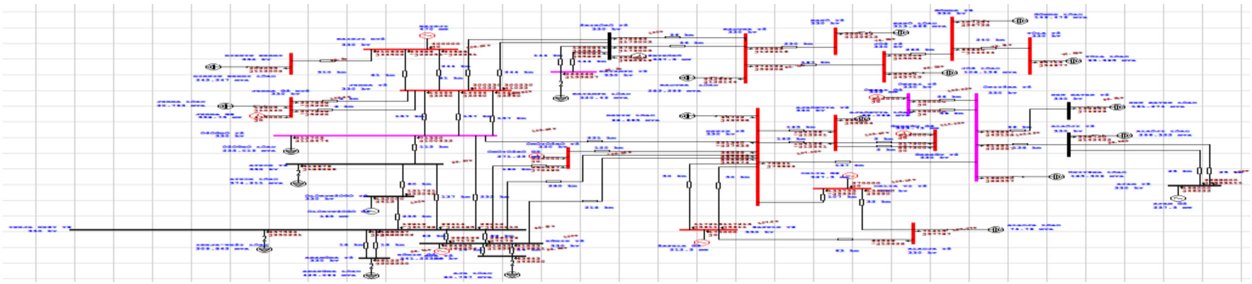

Fig. 9 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software (9th Load Increase at 0.18p.u)

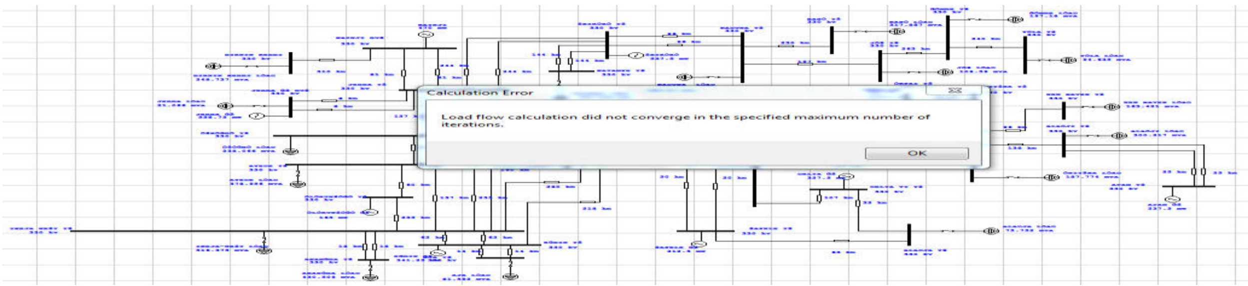

Fig. 10 Nigerian 30 Bus 330kV Transmission Network Modelled in ETAP 12.6 Software at Bifurcation Point (10th Load Increase at 0.20p.u)

IV. RESULTS AND DISCUSSION

The results obtained from the continuation power flow are shown in tables 2 and 3 and figs.11 and 12 respectively.
Table 1 Summary of Load Demand Using Continuation Power Flow

Loading Factor (P.U)	Total Load Demand (MW)
0.02	3069.835
0.04	3127.286
0.06	3183.982
0.08	3239.851
0.10	3299.140
0.12	3352.075
0.14	3408.032
0.16	3463.868
0.18	3519.653
0.20	3362.760

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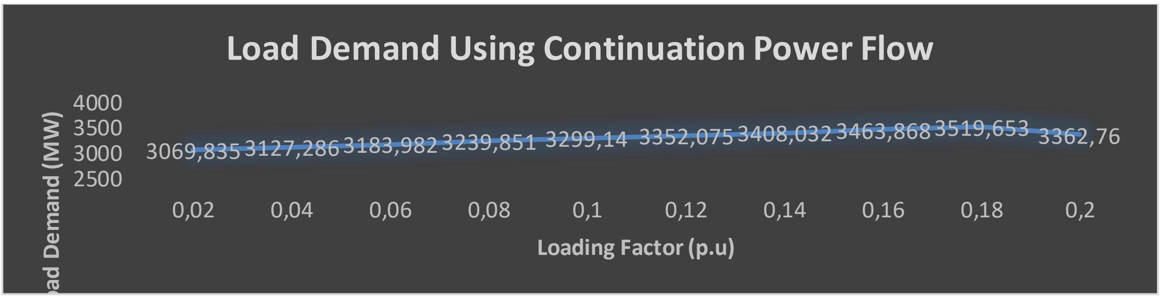

Fig. 11 Graph Showing Load Demand Using Continuation Power Flow

Table 2 Allowable Load Increment Before Voltage Collapse (Loading Margin)

Loading Condition	**8th Load Increase**	**9th Load Increase**
Loading Factor (P.U)	0.16	0.18
Total Load Demand (MW)	3463.868	3519.653
Loading Margin (MW)	55.785	

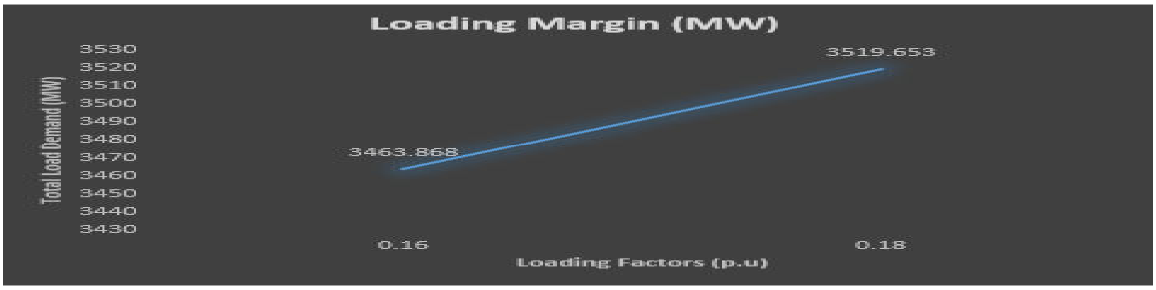

Fig. 12 Graph Showing Loading Margin

V. CONCLUSION

Continuation Power Flow method was used to run load flow analysis in ETAP 12.6 software environment. The continuation power flow analysis showed that from a generation load of 4000MW, 3519.653MW was the highest load sustained at a loading factor of 0.18p.u.

The analysis also showed that at a loading factor of 0.20p.u, the continuation power flow failed to run depicting that beyond 3519.653MW, system collapse may occur. This is so because voltage collapse has shown.

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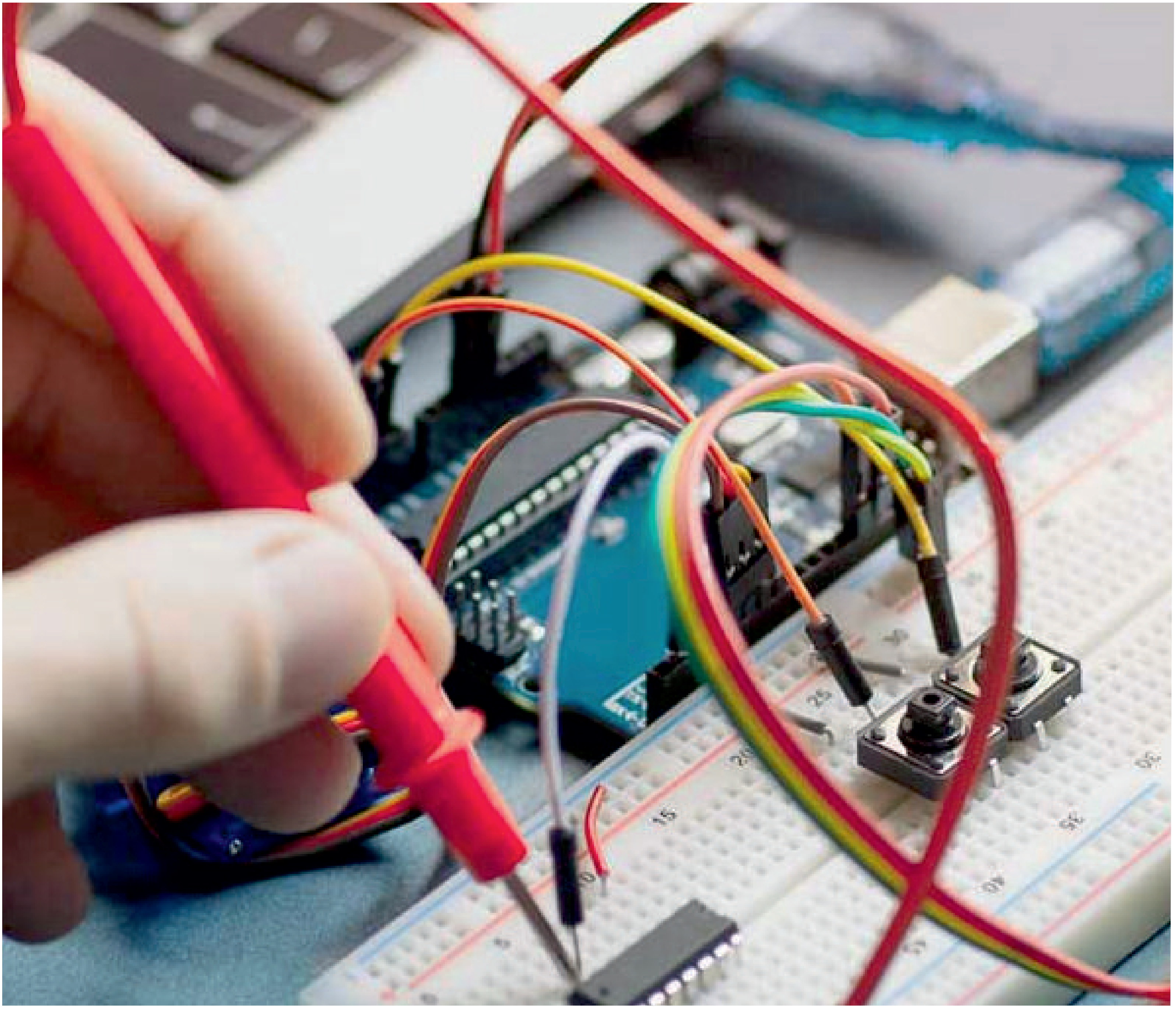

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