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# Model of System Microgrid in radial Topology using Euler-Lagrange Equation.

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**Abstract.** The need of power and equipment that can serve to distribute the electric energy becomes primordial things this period that almost of domains' specialists work in, and one of this equipment is microgrid system that gain more and more places in not just industrial area but almost domestic area, however, rural or urban. This equipment is can be worked in synchronization with the main grid or worked alone provides its own needs in alimentation and characteristics via the distributed generators. In fact, micro-grid is a complex system controlled and powerful in sense of distribution energy with minimum losses that have variety in specifics and also in the mode of working but haven't a specific model that presents its function correctly. So, our study is interested in the analytical modeling of the micro-grid via the Euler Lagrange equations. After using the (ELE) method as tools to model the micro-grid, we simulate it through MATLAB/Simulink. The simulation result shows that the model presents the behavior of the micro-grid in mode isolated and connected in radial topology.

## 1 Introduction

Day by Day, the world has its needs arise especially in electricity's domain that has evolved from the year of 1785 when we had the discover of what we call it now coulomb law (1).and the obsession of having an intermittent and more efficient power request from searchers to keep working hard to find a solution in relation of the domain.
With the creation of many notions like distributed generation where the generation of electricity not keep it close in one local but decentralized and the connection of things and big data (2) let's the searchers have new version of equipment of distribution like the micro-grid that a notion comes with the Smart grid like a cyber-physique system does two missions that were separated for a long time which is the transmission and the distribution. The micro-grid is a tool of transmission and distribution heat and power to any customers local (3). However, its position (rural/urban) and, however, also the source of the energy that will be found in the customers local as solar energy, micro-turbines, wind power and fossil fuel nevertheless it can increase the production of greenhouse gases like CO2 and micro-grid not have only the characteristic of using renewable energy like sources and reduce the emission of CO2 but also has two modes of function ON-grid and OFF-grid, even if the MG is connected or not to the main grid. Also, the MG has two principal topology radial or loop in depending on the configuration of the system.

## 2 MATERIAL AND METHOD

### 2.1 System modeling

The International Electrotechnical Commission (IEC) standard micro-grid system is used in this study as its figure shown below.

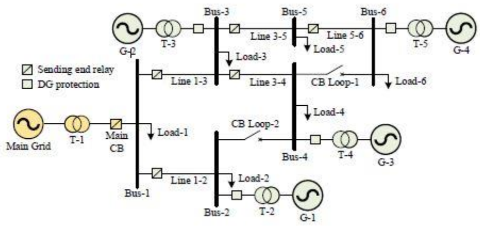


**Fig. 1.** A standard micro-grid System. (4)

### 2.2 Physiology of System Micro-Grid (IEC)

The Micro-grid (MG) is a two-way working equipment that can work in the mode connected with the main grid along with a step-up transformer (T-1 as mentioned in fig.1) and if we have an outage for any reason in the main grid the main circuit Breaker (CB) must cut the alimentation from the main grid and the supply in this case will be taken from the distributed generator (DER) that are appointed in the IEC system by G-1, G-2, G-3, G-4 and the micro-grid in the grid tied mode must keep the power needed from the loads get in feeder with security equipment and step-down transformer (T-2, T-3, T-4, T-5) and the frequency. Also, the particularity of MG is that it has bus bars instead of normal nodes that make its function changing.
The MG gives two topologies one radial when CB-loop 1 and CB-loop 2 was open and mesh (or loop) in case they are closed.

### 2.3 Parameters of the system studied

- **Line**
  Lines 1-2; lines 1-3; lines 3-4; lines 3-5; lines 5-6.
  Distance: 20 km each
  Resistance (Ω/km) :0.0424
  Inductance (H/km) :$1.39*10^{-4}$

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Capacitance (F/km): $5.01*10^{-9}$

- **Transformers**
  T-1 step-up, transmission factor: 79/13 kV
  T-2 and T-5 step-down, transmission factor: 0.575/13 kV
  T-3 and T-4 step-down, transmission factor: 0.4/13 kV
- **Generators**
  Main grid voltage: 79 kV, frequency: 50 Hz
  G-1 voltage: 575 V, frequency :50 Hz
  G-2 voltage: 0.4 kV, frequency:50Hz
  G-3 voltage: 13 kV, frequency:50Hz
  G-4 voltage: 575 V, frequency:50Hz
- **Loads**
  Load 1 :
  $R_1$=13Ω, $C_1$=0.2F, $L_1$=30H.
  Load 2 :
  $R_2$=5Ω, $C_2$=0.5F, $L_2$=5H.
  Load 3 :
  $R_3$=2.5Ω, $C_3$=0.3F, $L_3$=8H.
  Load 4 :
  $R_4$=6Ω, $C_4$=0.7F, $L_4$=13H.
  Load 5 :
  $R_5$=8Ω, $C_5$=0.9F, $L_5$=6.5H.
  Load 6 :
  $R_6$=2Ω, $C_6$=0.3F, $L_6$=5H.

### 2.4 Analytical modeling

Modeling as a general term is a prosperous science and the objective of our study is to establish a model in the form of differential equations to describe the functioning of the system in concrete and to achieve this goal, we will apply the Euler-Lagrange equation (ELE).

the ELE are equations to study the motion of the system through varying the Lagrangian which is written in the following form:

$$L(q,\dot{q},t) := T(q,\dot{q},t) - V(q,t) \qquad (1)\ (5)$$

$T$ : the total kinetic energy of the system.
$V$ : the potential energy of the system.

The Lagrange equations are described below:

$$\frac{d}{dt}\left(\frac{\partial T^*}{\partial \dot{q}}\right) - \frac{\partial T^*}{\partial q} + \frac{\partial D}{\partial \dot{q}} + \frac{\partial V}{\partial q} = e^s \qquad (2)\ (5)$$

D: Rayleigh dissipation function
$e^s$: generalized source effort
q= $[q_1,q_2,\dots,q_n]^T$: generalized displacements.
$\dot{q}$= $[\dot{q}_1,\dots,\dot{q}_n]^T$ : generalized flows.

After extracting the equations of motion of the microgrid system in differential form, these equations will allow us to establish the block diagram of each equation separately to simulate it afterwards in the MATLAB/Simulink.

## 3 RESULTS

The microgrid has two modes of function that can work connected to the main grid in the grid tied mode or disconnected in isolated mode (6), our study is focused in the modeling the system microgrid so we must touch each case separately.

### 3.1 Model of microgrid in grid tied mode

As presented before the microgrid in this mode takes power from the main grid and (DER). So, the model of the microgrid in this case is presented below.

$$l_{1eq}\frac{di_1}{dt} + l_2\frac{di_2}{dt} + l_4\frac{di_3}{dt} + l_5\frac{di_4}{dt} + l_{51eq}\frac{di_5}{dt} + C_{1eq}q_1 + \frac{q_2}{C_2} + C_{31eq}q_3 + \frac{q_4}{C_5} + C_{51eq}q_5 + R_{1eq}i_1 + R_2 i_2 + R_4 i_3 + R_5 i_4 + R_{51eq}i_5 = m_{T-1} * U_m \qquad (3)$$

With:

$$l_{1eq} = l_1 + l_{1-2} + l_{1-3} + l_2 + l_3 + l_{3-4} + l_{3-5} + l_4 + l_5 \qquad (4)$$

$l_1$: inductance of load 1 and $l_2$: inductance of load 2 and so on.

$l_{1-2}$: inductance of lines 1-2 and so on.

$$C_{1eq} = \frac{1}{C_1} + \frac{1}{C_{1-2}} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{1}{C_4} + \frac{1}{C_5} + \frac{1}{C_{3-4}} + \frac{1}{C_{3-5}} \qquad (5)$$

$C_1$: capacitance of load 1 and so on.
$C_{1-2}$: capacitance of lines 1-2 and so on.

$$C_{31eq} = \frac{1}{C_3} + \frac{1}{C_4} \qquad (6)$$

$$C_{51eq} = \frac{1}{C_4} + \frac{1}{C_5} + \frac{1}{C_{3-4}} + \frac{1}{C_{3-5}} \qquad (7)$$

$$R_{1eq} = R_1 + R_2 + R_3 + R_5 + R_{1-2} + R_{1-3} + R_{3-4} + R_{3-5} \qquad (8)$$

$R_1$: resistance of load 1 and so on.
$R_{1-2}$ : resistance of lines 1-2 and so on.

$$R_{51eq} = R_3 + R_4 + R_5 + R_{3-4} + R_{3-5} \qquad (9)$$

$m_{T-1}$: transmission factor of Transformer T-1.
$U_m$ : the nominal voltage of main grid.

The second equation is

$$l_2\frac{di_1}{dt} + \frac{q_1}{C_2} + R_1 i_1 + l_2\frac{di_2}{dt} + \frac{q_2}{c_2} + R_2 i_2 = m_{T-2} * U_{G-1} \qquad (10)$$

With:
$m_{T-2}$: transmission factor of Transformer T-2 and so on.
$U_{G-1}$ : the nominal voltage of generator G-1 and so on.

The third equation is

$$l_4\frac{di_1}{dt} + l_4\frac{di_3}{dt} + l_4\frac{di_5}{dt} + \left(\frac{1}{C_3} + \frac{1}{C_4}\right)(q_1 + q_3) + \frac{q_5}{C_4} + R_4(i_1 + i_3 + i_5) = m_{T-4} * U_{G-3} \qquad (11)$$

The fourth equation is

$$l_5\frac{di_1}{dt} + (l_5 + l_6 + l_{5-6})\frac{di_4}{dt} + l_5\frac{di_5}{dt} + \left(\frac{1}{C_5} + \frac{1}{C_6} + \frac{1}{C_{5-6}}\right)q_4 + \frac{1}{C_5}(q_1 + q_5) + R_5(i_1 + i_4 + i_5) + (R_6 + R_{5-6})i_4 = m_{T-5} * U_{G-4} \qquad (12)$$

The fifth equation is

$$(l_3 + l_{3-4} + l_{3-5} + l_4 + l_5)\frac{di_1}{dt} + l_4\frac{di_3}{dt} + l_5\frac{di_4}{dt} + (l_3 + l_{3-4} + l_{3-5} + l_4 + l_5)\frac{di_5}{dt} + \frac{1}{C_4}(q_1 + q_3 + q_5) + \frac{1}{C_5}(q_1 + q_4 + q_5) + \left(\frac{1}{C_{3-4}} + \frac{1}{C_{3-5}}\right)(q_1 + q_5) + (R_3 + R_{3-4} + R_{3-5} + R_4 + R_5)i_1 + R_4 i_3 + R_5 i_4 + (R_3 + R_{3-4} + R_{3-5} + R_4 + R_5)i_5 = m_{T-3} * U_{G-2} \qquad (13)$$

We give in Fig. 2 the inputs and the outputs of the realized model.

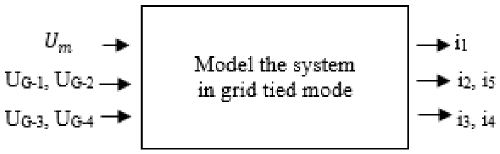


**Fig. 2.** Model inputs-outputs.

And the Simulation Result Is Presented Below:

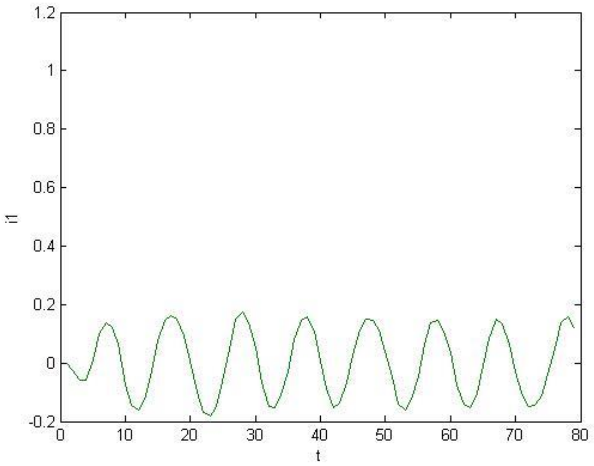


**Fig. 3.** Evolution of current i1(t).

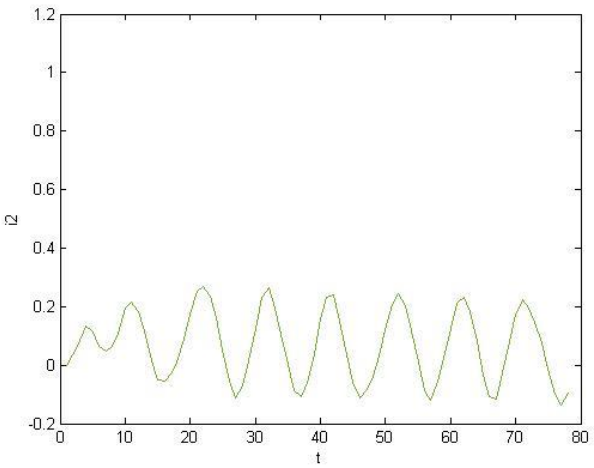


**Fig. 4.** Evolution of current i2(t).

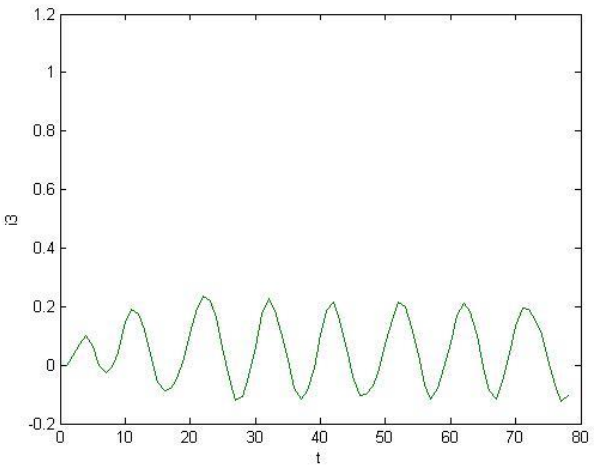


**Fig. 5.** Evolution of current i3(t).

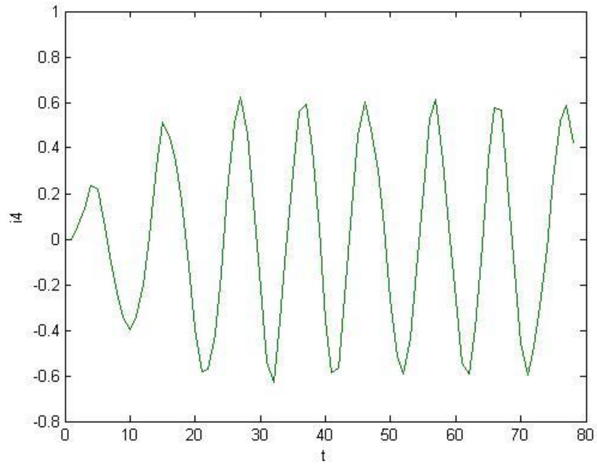


**Fig. 6.** Evolution of current i4(t).

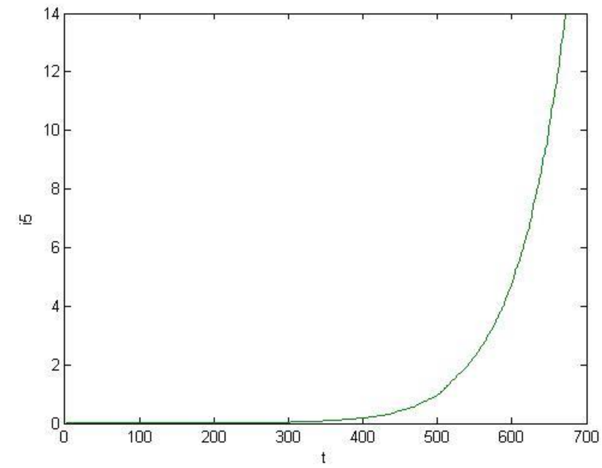


**Fig. 7.** Evolution of current i5(t).

### 3.2 Model of Microgrid in Disconnected Mode

The microgrid in the mode of is solely responsible for energy production. So, the energy in this case took from (DER) and the Main CB cut the alimentation from main Grid, this new data allows us to eliminate the first equation because i1=0A now.
The model of microgrid will be as presented below.
The first equation:

$$l_2 \frac{di_2}{dt} + \frac{q_2}{C_2} + R_2 i_2 = m_{T-2} * U_{G-1} \quad (14)$$

The second equation:

$$l_4 \frac{di_3}{dt} + l_4 \frac{di_5}{dt} + \left(\frac{1}{C_3} + \frac{1}{C_4}\right) q_3 + \frac{q_5}{C_4} + R_4(i_3 + i_5) = m_{T-4} * U_{G-3} \quad (15)$$

The third equation:

$$(l_5 + l_6 + l_{5-6}) \frac{di_4}{dt} + l_5 \frac{di_5}{dt} + \left(\frac{1}{C_5} + \frac{1}{C_6} + \frac{1}{C_{5-6}}\right) q_4 + \frac{q_5}{C_5} + R_5(i_4 + i_5) + (R_6 + R_{5-6}) i_4 = m_{T-5} * U_{G-4} \quad (16)$$

The fourth equation:

$$l_4 \frac{di_3}{dt} + l_5 \frac{di_4}{dt} + (l_3 + l_{3-4} + l_{3-5} + l_4 + l_5) \frac{di_5}{dt} + \frac{1}{C_4}(q_3 + q_5) + \frac{1}{C_5}(q_4 + q_5) + \left(\frac{1}{C_{3-4}} + \frac{1}{C_{3-5}}\right) q_5 + R_4 i_3 + R_5 i_4 + (R_3 + R_{3-4} + R_{3-5} + R_4 + R_5) i_5 = m_{T-3} * U_{G-2} \quad (17)$$

We give in fig.8 the inputs and the outputs of the realized model.

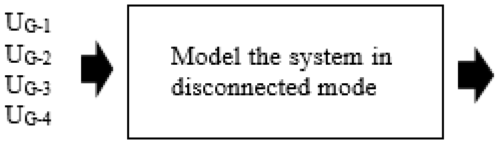


**Fig. 8.** Model inputs-outputs.

The simulation result is presented below.

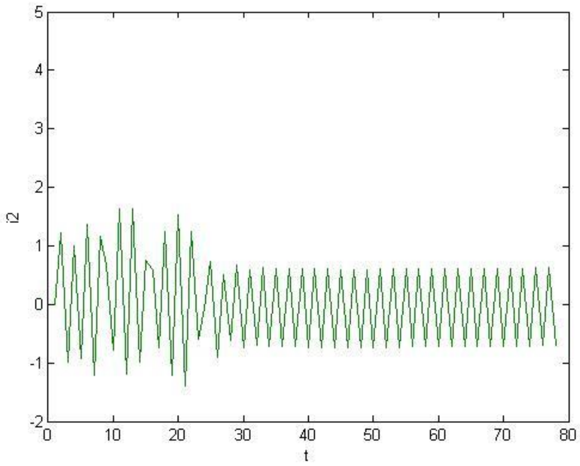


**Fig. 9.** Evolution of current i2(t).

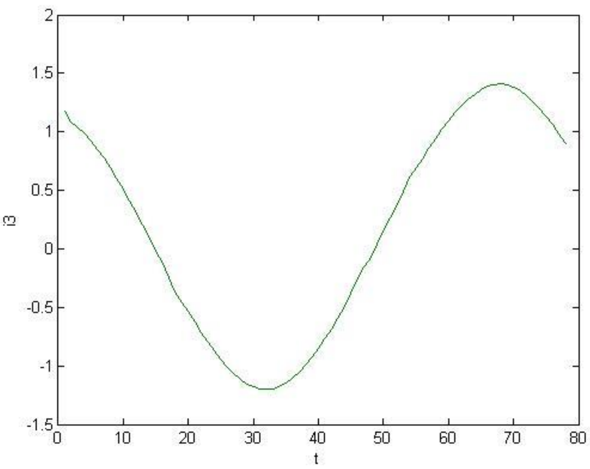


**Fig. 10.** Evolution of current i3(t).

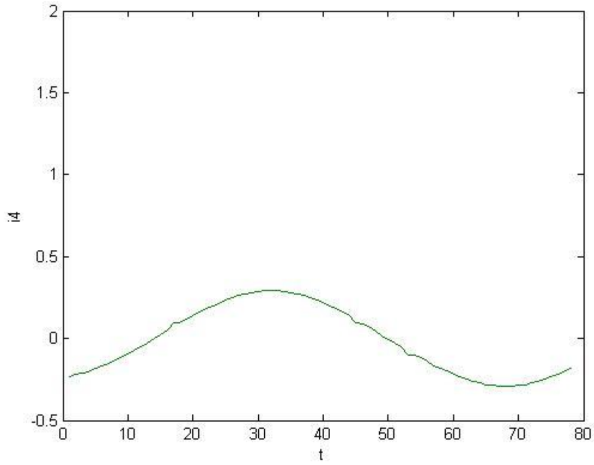


**Fig. 11.** Evolution of current i4(t).

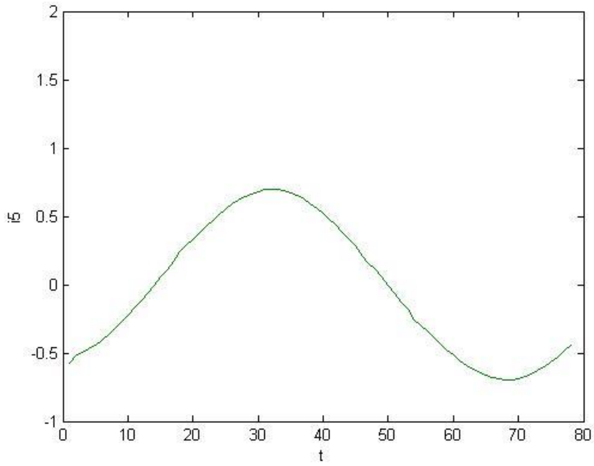


**Fig. 12.** Evolution of current i5(t).

## 4 DISCUSSION

In our modeling of system micro-grid, we are taken just the configuration radial and we simulated the two modes of function as connected or isolated from the main grid and we know that the function of the micro-grid in modes connected isn't like in mode isolated and the simulation result present that isn't the same. So, for the mode connected we have five inputs correspond to the voltage of the main grid and voltage of distributed generators G-1, G-2, G-3, G-4 and five outputs which are the current generated from the main grid i1 (t) and i2 (t) generated from G-1, i3 (t) generated from G-3, i4 (t) generated from G-4 and i5 (t) generated from G-2.

From figure 3,4,5 until 6 we notice that we have sinusoidal signals with same frequency imposed by the main grid and you know that the micro-grid in modes connected in its normal function has its frequency imposed from the main grid and not from distributed generators and for the current i5 (t) we have an exponential signal indeed we know that the sum of sinusoidal signals gives sinusoidal signals and even in case of integration and derivation but for the current corresponds to G-2 we have falling of sinusoidal fidelity.

For mode isolated we have four inputs which are the voltage of distributed generators G-1, G-2, G-3, G-4 and four outputs that are the current correspond to each generator and we notice from figure 9,10,11,12 that each signal of current has its proper frequency because the alimentation from the main grid stopped supplying and stop also imposed the frequency. So, each generator imposed its frequency and the difference in amplitudes find its cause in non-uniqueness of the voltage of each one. For figure 9 we notice that i2 (t) passed through a transitional regime to steady state in t=30s. We infer from study that the model in the verification steps gives results as it must be because it corresponds well to the operating mode of the system and gives results which describe this operation.

## 5 CONCLUSION

The system micro-grid is one of a complex system as a cyber-physique system that we will find it everywhere we need distribution with minimal reduction in losses transmission lines. So, as it powerful equipment our attention must focus to understand this equipment as much as possible that's why we are thinking to this study because to work with micro-grid we need its model close it and in our study we are taking micro-grid in radial topology with the two modes of function and gives for each case its proper model then simulated in MATLAB/Simulink and the domain of electric equipment has it features in its diversity and we have a continuous development in this equipment that need more studies.

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