Transient Stability Analysis of a 5-Bus Power System via MiPower

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Abstract— this paper describes Transient Stability Analysis of a 5-bus power system. For transient stability analysis, MiPower, an immensely featured and astonishingly obliging software, is utilized. One of the major challenges in a liberalized power system context is the capability to uphold system stability. The precise significance and paramount necessity of more regular and in-depth power system stability is demonstrated clearly by the recent blackouts in different countries. The bounds of stability and the consistency and competence of the power system, therefore, should be well-known beforehand to the power system engineers as instability occurrences can cause noteworthy damage thriftily [12]. Hence, the investigation and recognition of the stability of power system is the main objective of this paper. MiPower software techniques are used to implement the modeling and simulation of power system and stability issues are studied.
Key words: Load Flow, MiPower Software, Power System, Transient Stability Analysis

I. Introduction

The power sector, in the prevailing scenario, has been experiencing persistent growth in generation, transmission and utilization. With the existing voluminous size of network, along with the swift development in supply and demand, the traditional methodologies to study the various power system networks have evidenced to be ineffective. Thus, innovative computational and scheduling approaches are in demand by power system consultants. A number of power system simulation software packages have been developed for performing an extensive range of power system design and analysis studies. MiPower is one of those powerful software and is extremely user-friendly.

MiPower is an opportunity and platform for the academicians, researchers and committed engineers to solve problems dealing with recent advances in power systems. MiPower features take account of an excellent Windows Graphical User Interface with centralized database. Various power system studies including steady state, transient and electro-magnetic transient analysis can be performed with utmost accuracy and tolerance. It is designed to assess the risk of voltage instability and margin of stability during sudden disturbances, under steady state conditions. Due to the availability of a number of toolboxes in bulk which have been fashioned for many diverse applications, it has gained popularity amidst the power consultants and engineers.

In this paper, a detailed description of the transient stability analysis is presented. A case study example along with Simulation model and results is examined afterwards. Towards the end, concluding remarks on the subject of the significance of the paper are presented.

II. Transient stability studies

Transient Stability Analysis is the most important exploration into the operation of power systems as a consequence of the growing hassle on the existing power system networks. The information obtained by conducting transient stability analysis can benefit the protection engineers in making a knowledgeable judgment owing to the design of the protection scheme for a power system [13].

Power system transient stability program is the tool to analyze the behavior of the power system during large disturbances, in which the excursions of rotor angles of synchronous machines are studied with respect to each other [10]. The determination of the critical clearing time after a three phase fault in the power system is the paramount and notable purpose of transient stability study. Critical clearing time refers to the time within which the fault should be distinguished and cleared so as to ascertain that the synchronism is not lost.

The transient stability simulation of power systems lays emphasis on analyzing the stability of a power system in a very small frame of time ranging from a few seconds to several tens of seconds. This paper is written to aid the enthusiastic power system engineers in recognizing the concept of stability studies. Instead of in depth mathematical analysis, emphasis is laid on understanding the physical concept and interpreting the results [10]. It is extremely necessary for the power system operator to know the influence of disturbances on various critical arrangements such as generators from stability viewpoint. For the assessment of stability in case of huge disturbances (such as faults), it is important to know the precise transient response of the system under consideration. Thus, transient stability study is of utmost importance in an electrical power system network.

A. *Stability and Classification*

The stability of a system refers to the ability of a system to return back to its steady state when subjected to a disturbance. The power system stability can be defined as the ability of the power system to return to steady state without losing synchronism. Generally, power system stability is classified into Steady State, Transient and Dynamic Stability.

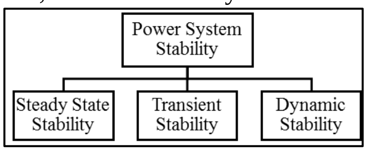

Fig. 1: Stability Classification

– Steady State Stability refers to the ability of a power system to regain and maintain synchronism after a small slow disturbance. The small slow disturbances include normal load variations [6].
– Transient Stability encompasses the study of the power system after a large sudden disturbance. After a large sudden disturbance, the machine power (load) angle of the synchronous alternator changes due to sudden acceleration of the rotor shaft. In view of that, the transient stability study focuses to make sure whether the

load angle returns to a steady value succeeding the clearance of the disturbance.

- The ability of a power system to maintain stability under continuous small disturbances is investigated under the name of Dynamic Stability (also known as small-signal stability). It is concerned with small disturbances lasting for times of order of 4 to 10 seconds with the inclusion of automatic control devices [5].

III. CASE STUDY

The Transient Stability Analysis is discussed below using case study example which has been taken from Ref. [8, 9]. A 5-bus system is taken in this case study whose single line diagram is shown in Figure 2. The 5-bus system has three generating units, four lines and two transformers and two loads. The details can be obtained from Ref. [8, 9]. Per-unit transmission line series impedances and shunt susceptances are given on 100 MVA base, generator's transient impedance and transformer leakage reactances are given in the accompanying table. Values given are on 100 MVA Base. Frequency = 60 Hz.

It is assumed that a 3-phase fault occurs on line 4-5 near bus 4 and the fault is cleared by simultaneously opening the circuit breaker at the ends of the line 4-5 at 0.225 Seconds (fault clearing time). In this case study, we check the stability of machine 1 and machine 2 by plotting the swing curve and analyzing it.

A. *Generator Details*

G1= 400 MVA, 20 kV, X_d'=0.067 pu, H= 11.2 MJ / MVA
G2= 250 MVA, 18 kV, X_d'=0.10 pu, H= 8.0 MJ / MVA
G3= 1000 MVA, 230 kV, X_d'=0.00001 pu, H= 1000 MJ / MVA (Infinite Bus Modeling)

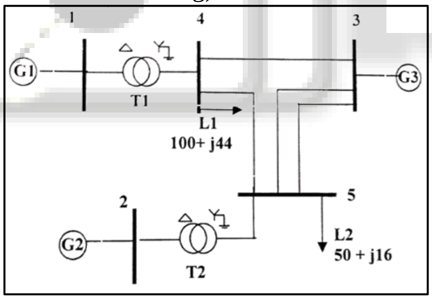

Fig. 2: 5-bus system for Transient Stability analysis

Bus Code p-q	Impedance Zpq	Line Charging Y'pq/2
3-4	0.007+j0.04	j0.041
3-5(1)	0.008+j0.047	j0.049
3-5(2)	0.008+j0.047	j0.049
4-5	0.018+j0.110	j0.113

Table 1: Impedances and line charging for the sample system

Bus Code 'p'	Generation		Load		Specified Voltage
	MW	MVAR	MW	MVAR	
1	350	71.2	0	0	1.03
2	185	29.8	0	0	1.02
3	800	0	0	0	1.0
4	0	0	100	44	Unknown
5	0	0	50	16	Unknown

Table 2: Generator and Load details

B. *Transformer Details*

T1= 20/230 kV, 400 MVA, leakage reactance =0.022 pu
T2=18/230 kV, 250 MVA, leakage reactance =0.040 pu

For preparing the simulation model to perform transient studies in MiPower, the procedure is followed as given in Ref. [8, 9].

IV. SIMULATIONS AND RESULTS

The complete simulation model for the given 5-bus system is as shown in figure 3. For any transient study simulation, it is indispensable to explain the steady state condition and investigate the load flow problem to establish the initial condition which is utilized in solving the differential equations used in the transient problem. Hence, at the outset, load flow study is conducted on the 5-bus power system to attain the initial condition for transient stability analysis.

A. *Results of Load Flow*

The load flow study is conducted on the 5-bus power system using Fast Decoupled Load Flow Method. A part of the report obtained after conducting load flow study is given below.

```
ITERATION    MAX P BUS     MAX P    MAX
Q BUS     MAX Q
   COUNT            NUMBER    PER  UNIT
NUMBER  PER UNIT
---------    ---------  --------    ---
------  --------
1.263  1          1     3.500         4
0.016  2          4     0.087         4
0.000  3          4     0.002         4
0.000  4          4     0.000         4
0.000  5          4     0.000         1
0.000  6          1     0.000         1
```

Table 3: Load Flow

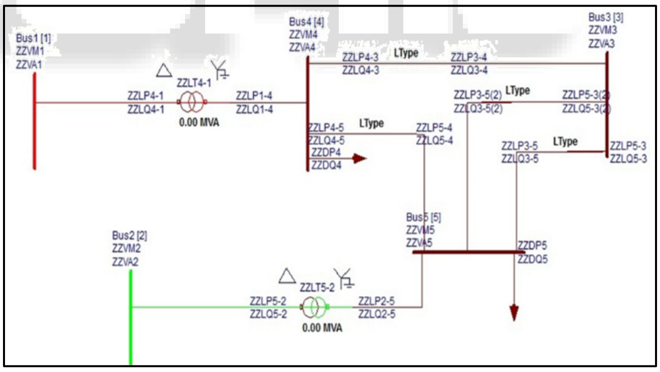

Fig. 3: Simulation model of 5-bus system for Transient Stability studies

```
Number of p iterations: 3 and Number of
q iterations: 5

BUS VOLTAGES AND POWERS

    NODE     FROM   V-MAG  ANGLE       MW
MVAr         MW     MVAr      MVAr
     NO.     NAME    p.u. DEGREE      GEN
GEN        LOAD     LOAD     COMP
```

```
        1     Bus1  1.0300   8.90  350.000
71.200     0.000    0.000    0.000
        2     Bus2  1.0200   6.39  185.000
29.800     0.000    0.000    0.000
        3        Bus3   1.0000    0.00     -
380.502   -26.497        0.000       0.000
0.000  <
        4     Bus4  1.0175   4.68    0.000
0.000   100.000   44.000    0.000
        5     Bus5  1.0109   2.27    0.000
0.000    50.000   16.000    0.000
-------------------------------------------
```



```
NUMBER  OF  BUSES  EXCEEDING  MINIMUM
VOLTAGE LIMIT (@ mark) :    0
NUMBER  OF  BUSES  EXCEEDING  MAXIMUM
VOLTAGE LIMIT (# mark) :    0
NUMBER OF GENERATORS EXCEEDING MINIMUM Q
LIMIT (< mark)  :    1
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q
LIMIT (> mark)  :    0
```

```
TRANSFORMER FLOWS AND TRANSFORMER LOSSES

Sl.NoCS     FROM     FROM      TO      TO
FORWARD               LOSS          %
           NODE     NAME     NODE    NAME
MW     MVAr         MW      MVAr LOADING
   1   1           4       Bus4          1
Bus1 -349.987  -44.745   0.0026  26.4537
86.7#
   2   1           5       Bus5          2
Bus2 -184.999  -16.300   0.0014  13.4998
73.5$
```

```
! NUMBER OF TRANSFORMERS LOADED BEYOND
125%          :    0
@ NUMBER OF TRANSFORMERS LOADED BETWEEN
100% AND 125% :    0
# NUMBER OF TRANSFORMERS LOADED BETWEEN
75% AND 100% :    1
$ NUMBER OF TRANSFORMERS LOADED BETWEEN
50% AND  75% :    1
^ NUMBER OF TRANSFORMERS LOADED BETWEEN
25% AND  50% :    0
& NUMBER OF TRANSFORMERS LOADED BETWEEN
1% AND  25% :    0
* NUMBER OF TRANSFORMERS LOADED BETWEEN
0% AND   1% :    0
```

```
LINE FLOWS AND LINE LOSSES

SLNO CS       FROM        FROM         TO
TO       FORWARD          LOSS          %
           NODE     NAME     NODE    NAME
MW     MVAr        MW      MVAr LOADING
```

```
LINE FLOWS AND LINE LOSSES

SLNO CS       FROM        FROM        TO
TO       FORWARD          LOSS         %
           NODE     NAME     NODE   NAME
MW     MVAr        MW     MVAr LOADING
---- -- -------- -------- -------- ----
---- -------- -------- -------- -------
- -------
   3   1          4        Bus4          3
Bus3  210.573   11.960   3.0157   8.8875
207.3!
   4   1          3        Bus3          5
Bus5  -86.472  -11.712   0.6019  -6.3713
87.3#
   5   1          4        Bus4          5
Bus5   39.418  -11.215   0.2702 -21.5963
40.3^
   6   1          3        Bus3          5
Bus5  -86.472  -11.712   0.6019  -6.3713
87.3#
```

```
! NUMBER  OF  LINES  LOADED  BEYOND   125%
:    1
@ NUMBER  OF  LINES  LOADED  BETWEEN  100%
AND 125% :    0
```

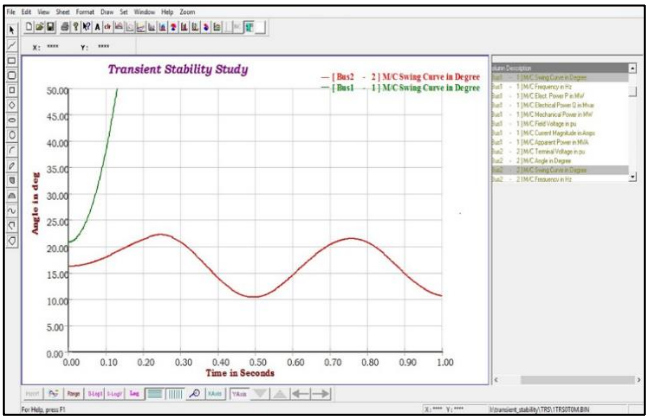

Fig. 4: Swing Curves for Machine 1 and Machine 2

```
! NUMBER  OF  LINES  LOADED  BEYOND   125%
:    1
@ NUMBER  OF  LINES  LOADED  BETWEEN  100%
AND 125% :    0
# NUMBER  OF  LINES  LOADED  BETWEEN   75%
AND 100% :    2
$ NUMBER  OF  LINES  LOADED  BETWEEN   50%
AND  75% :    0
^ NUMBER  OF  LINES  LOADED  BETWEEN   25%
AND  50% :    1
& NUMBER  OF  LINES  LOADED  BETWEEN    1%
AND  25% :    0
* NUMBER  OF  LINES  LOADED  BETWEEN    0%
AND   1% :    0
----------------------------------------
----------------------------------------
-
----------------------------------------
----------------------------------------
-
BUSES BETWEEN WHICH ANGLE DIFFERENCE IS
> 30 degrees ARE: ZERO
----------------------------------------
----------------------------------------
-
ISLAND        FREQUENCY        SLACK-BUS
CONVERGED(1)
------ --------- ----------- ----------
--
    1  60.00000            3        1
```

To simulate three phase fault, three phase fault is given as a disturbance on bus 4. 'Change in transmission Line Parameters' is given as a disturbance to account the consequence of opening of breaker. A part of the report of transient study stability is given below.

```
Time =    0.00000 Seconds
Intermediate results for Machines
GNo  Name        Voltage  Angle      Delta
Freq     Pgen     Qgen     Pmech   Efd/Slip
              pu           Degree    Degree
Hzs.      MW       MVAR     MW       pu/PU

1        Bus1      1.03        8.9      20.8
60       350     71.2       350        1.1
2        Bus2      1.02       6.39      16.2
60       185     29.8       185      1.06
3          Bus3        1           0 -0.00218
60      -381     -26.5     -381         1
```

Maximum rotor angle difference: 20.84325 b/w buses: 1 and 3

3 phase fault 0.00000 4 Bus4 kp 1 kq 0 Iterations 10 dpmax 0.064557 dqmax 0.003461

```
Time =    0.00100 Seconds
Intermediate results for Machines
GNo  Name        Voltage  Angle      Delta
Freq     Pgen     Qgen     Pmech   Efd/Slip
              pu          Degree    Degree
Hzs.     MW       MVAR     MW       pu/pu
--- -------- ------- -------- ------- -
------ ------- ------- ------- --------
1        Bus1     0.275      20.1      20.8
60      5.93      339      350       1.1
2        Bus2     0.908      6.55      16.2
60       162      129      185      1.06
3        Bus3         1  -0.00455   -0.0022
60       414  3.02e+003    -381         1
----------------------------------------
----------------------------------------
-
Maximum   rotor   angle   difference   :
20.84410 b/w buses : 1 and 3
Island        1  Common  system  frequency
60.000
```

The swing curve for machine 1 and machine 2 are obtained as shown in Figure 4. From the Figure 4, it can be concluded that Machine 1 happen to be unstable while machine 2 is stable.

V. CONCLUSIONS

This paper presents the Transient Stability analysis of a 5-bus Power System. A Simulation of Transient Stability of 5-Bus system using MiPower software is demonstrated in this paper by applying three phase to ground fault as a disturbance. This paper aims to present a methodology to transient stability analysis of electrical power system in order to assist and escort in the direction of the enhancement of stability analysis. In this paper, an attempt is made to explain the importance of the stability studies to practicing engineers. The stability studies should be conducted to ascertain the transient and dynamic behavior of the power system, following the disturbance. Modeling of power system for stability studies is discussed along with a case study to analyze and interpret the results.

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