ISSN 2250-3153

# Study and Analysis of Transient Stability in Power Systems

**Mahasweta Bhattacharya, Nilanjan Mukherjee**

***Abstract-*** A power system is considered to be transiently stable if it can regain and maintain synchronism after a sudden disturbance. Circuit breakers play a pivotal role in maintaining transient stability of power systems. Using high speed circuit breakers, transient stability can be achieved efficiently in power systems. The project has aimed at the improvement of the transient stability using high speed breakers. The implementation of the technique has been carried out through MATLAB R2009b.

***Index Terms*-** Transient stability , high speed breaker, restriking voltage, RRRV, resistance switching, manual switching, power system

## I. INTRODUCTION

A power system has transient stability if after a large sudden disturbance it can regain and maintain synchronism. A large sudden disturbance includes application of faults, clearing of faults, switching on and off the system elements (transmission lines, transformers, generator, loads etc).Usually, transient stability studies are carried out over a relatively short time period that will be equal to the time of-3-5 cycles. The analysis is I a relatively short- time period that will be equal to the time of-3-5 cycles. The analysis is carried out to determine whether the system loses stability during the first swing or not. In case the power system remains stable, it is assumed that subsequent swings will diminish and the power system will remain stable, as usually happens.

However, circuit breakers play a pivotal role in maintaining the transient stability of power system. The best method of improving transient stability is the use of high speed circuit breakers. The quicker a breaker operates, faster the fault is removed from the system and better is the tendency of the system to restore to normal operating conditions. The use of high speed breaker has materially improved the transient stability of the power systems and does require any other method for the purpose. Therefore to obtain faster and proper breaker operation, the restriking of the arc has to be prevented between its contacts. The arc quenching phenomenon can be explained as follows:

*"At zero crossing instant of ac wave, the arc vanishes, which can be prevented from recycling by rapid buildup of dielectric strength of the medium between the contacts by injecting various insulating fluids like air, oil, SF6 etc(between the contacts) under pressure so as to deionize the arc path and thus providing a transition from current carrying state to voltage insulating states of the contacts"*

## II. MATHEMATICAL FORMULATION

The expression of restrikìng voltage can be given as:

$$v = v_{MAX}\left(1-\cos\left(\frac{t}{\sqrt{LC}}\right)\right)$$

For the above expression of restriking voltage, $V_{MAX}$ is the peak value of recovery voltage (phase -to-neutral),t is time in seconds, L is inductance in henrys, C is the capacitance in farads and v is the restriking voltage in volts.

The maximum value of restriking voltage is $2V_{MAX}$ and occurs at $t=\frac{\pi}{\omega}$ or $t=\pi\sqrt{LC}$

The rate of rise of restrikìng voltage (RRRV) can be expressed as follows:

$$RRRV = \frac{dv}{dt} = \frac{v_{MAX}}{\sqrt{LC}}.\sin\frac{t}{\sqrt{LC}}$$

Hence maximum value of RRRV, $RRRV_{MAX} = V_{MAX}/\sqrt{LC}$

Where high RRRV is expected circuit breakers with shunt resistances are employed. Now for ensuring exponential buildup of voltage across the breaker to 50Hz recovery voltage ,without overshoot, instead of exhibiting the oscillatory doubling effect associated with an achieve critical damping is $1/2\sqrt{LC}$ . Inclusion of shunt resisters increases the rupturing capacity of the breaker. Thus, minimization of the restriking voltage will resuit in proper and faster operation of the circuit breaker and the transient stability limit will not be exceeded.

## III. CALCULATION

f=frequency of restriking transient

$f=\frac{1}{2\pi\sqrt{LC}}$=863.138 Hz, where L=5mH and C=6.8µF

Tp= $\pi\sqrt{LC}$= 0.58ms

Maximum value of restriking voltage=$2V_{MAX}$=(2*9.3)=18.6V which is obtained at 0.58ms

However in case of working model,

Restriking voltage=12=9.33(1-cos(1/$\sqrt{LC}$*t))

1.2856=1-cos(1/$\sqrt{LC}$*t)

T=0.343ms

Thus the time of manual switching is at 0.343ms.

Therefore, RRRV=(18.6-12)/(0.58-0.343)=6.6/0.237=27.848 V/ms.

## IV. MATLAB IMPLEMENTATION

The restriking voltage has also been obtained through MATLAB simulation.

ISSN 2250-3153

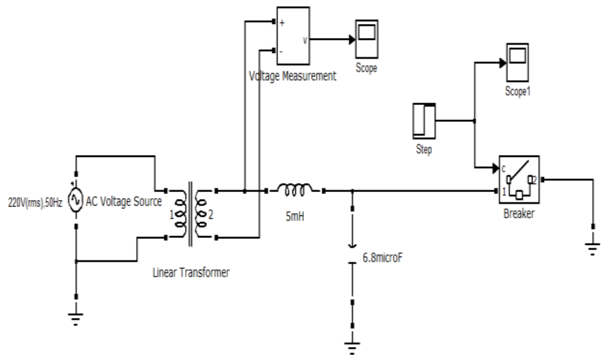


**Fig. 1 Simulink model for manual switching**

The complete system has been represented in terms of simulink blocks in a single integral model. Initially, the circuit breaker is closed but opens after some time and the restriking voltage transient is as shown in fig.1. The reactor representing the reactance of the transmission line is taken as 5mH. The line to ground capacitance is 6.8µF. The circuit breaker is externally controlled through the step pulse as shown in figure above. The restriking voltage as obtained in MATLAB simulation is shown in fig. 2

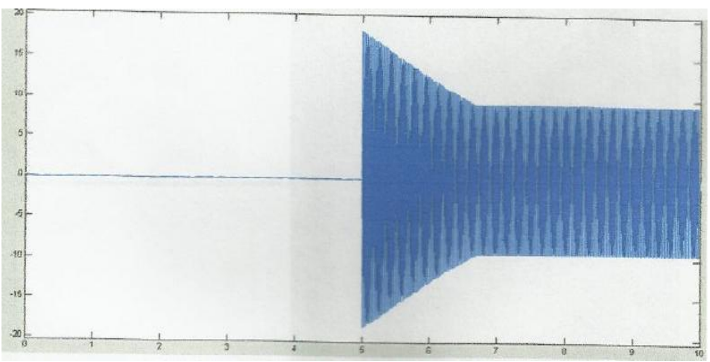

**Fig.2 Graph showing restriking voltage transient across breaker contacts**

Restriking voltage obtained from MATLAB simulation =18.5V

Here, the values of L and C are same as that taken in the hardware model.

Similarly, the circuit for resistance switching has also been developed, hence minimizing the restriking voltage. In case of resistance switching, a 2Ωresistor is connected across the circuit breaker as shown in the diagram below.

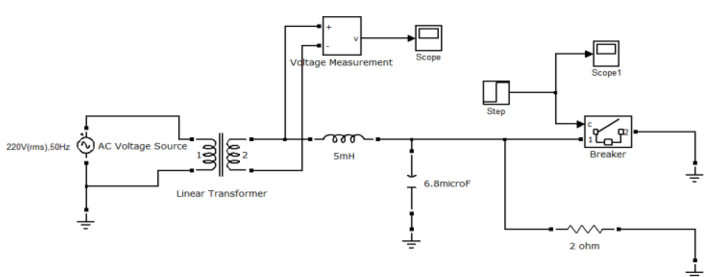


**Fig.3 Simulink model for resistance switching**

The graph obtained through MATLAB simulation is shown below.

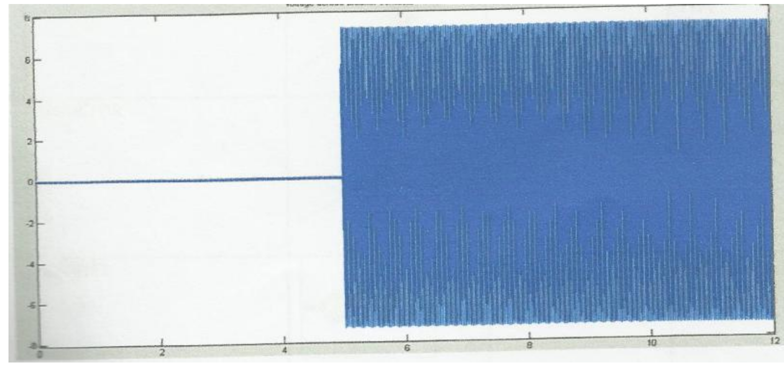

**Fig.4 Graph showing restriking voltage in resistance switching**

**HARDWARE MODEL**

The hardware model for obtaining the restriking voltage has been designed as follows.

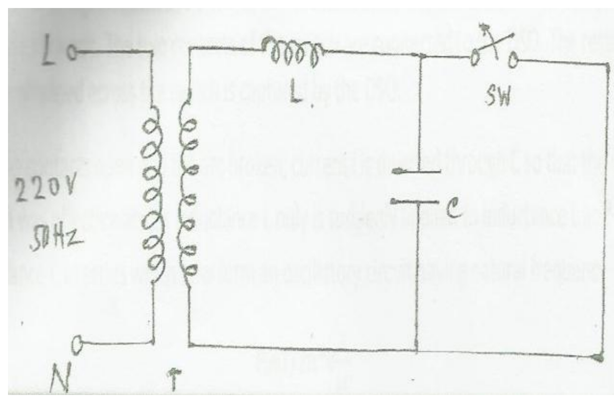


**Fig.5 Hardware model for manual switching**

## V. COMPONENT SPECIFICATION

| Sl No | Component | Diagram | Quantity | Specification |
|---|---|---|---|---|
| 1 | Capacitor |  | 1 | 6.8µF, 50V, $85^0$C, ELECTROLYTIC TYPE |
| 2 | Inductor |  | 1 | 5mH |
| 3 | Resistor |  | 2 | 100Ω each |

| | | | | |
|---|---|---|---|---|
| 4 | Transformer |  | 1 | 220/6.0V, 300mA |

## VI. DESCRIPTION

L represents the inductance per phase of the system upto the fault point and C represents the capacitance to the earth of the circuitbreaker porcelain brushing. The switch S1 acts as the circuit breaker which here is manually opened under short circuit. The two contacts of the switch are connected to the DSO. The restriking voltage obtained across the switch is captured by the DSO. With the contacts open and the arc broken, the current I is diverted through C so that the voltage V which was effective across inductance L only is suddenly applied to inductance L and capacitance C in series which now form an oscillatory circuit having natural frequency

$$F_n = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

The initial charging current surge tends to carry the voltage across the capacitor and therefore across the circuit breaker contacts to double its equilibrium value, i.e, 2Vmax, this is the restriking voltage transient which tends to re-establish the arc in the circuit breaker.

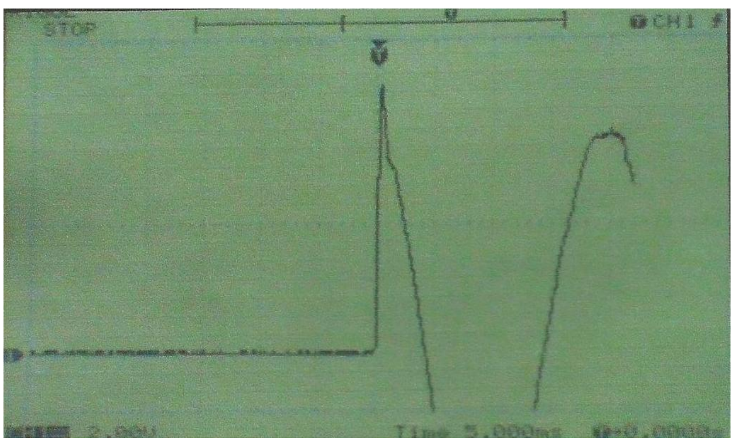


**Fig.6 Graph obtained in DSO by manual switching**

- Restriking voltage obtained from the DSO= 11.8V,i.e 12V
- Peak time obtained from the DSO= 0.5ms

## VII. RESISTANCE SWITCHING

The circuit diagram of resistance switching is as follows :

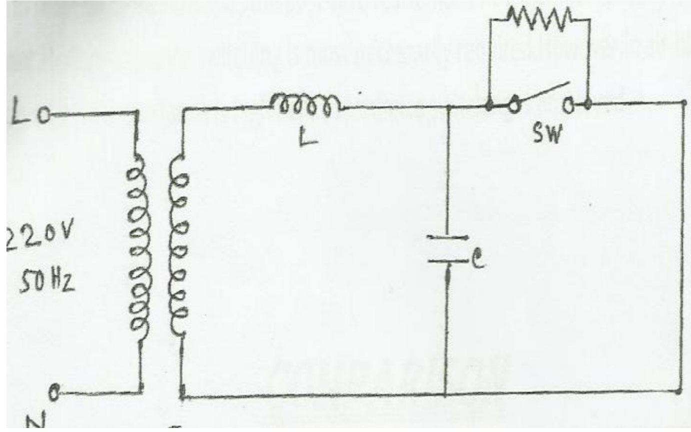


**Fig.7 Hardware model for resistance switching**

In case of resistance switching a resistor is placed across the circuit breaker (here a switch) as shown in the diagram above. The graph obtained from the DSO with resistance switching is as follows:-

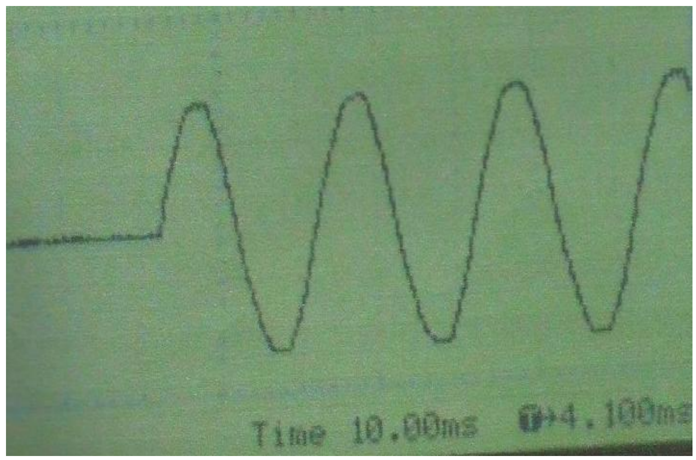


**Fig.8 Graph obtained in DSO by resistance switching**

The resistor performs the following functions :

1. It reduces RRRV and thus reduces the burden on the circuit breaker.
2. It ensures the dampening of the high frequency restriking transients during the switching out inductive or capacitive load.

In plain oil-circuit breaker, the post-zero resistance of the contact space is constant. Hence, resistance switching is most necessarily required. However, in air-blast circuit breaker post zero resistance is high hence resistance switching is employed.

## VIII. COMPARISON

The comparison of mathematical analysis, MATLAB and hardware analysis can be done as follows :

| PARAMETERS | Mathematical Analysis | MATLAB | Hardware |
|---|---|---|---|
| RESTRIKING VOLTAGE | 18.6V | 18.5V | 12V |
| PEAK TIME | 0.58ms | 0.57ms | 0.5ms |

In case of MATLAB and mathematical model, the transformer impedance(leakage impedance and magnetizing reactance) has been neglected. The resistance of the transformer winding results in damping of the voltage transient. Moreover, manual operation of switching has also not been done at the instant of maximum voltage transient. However the time of manual switching is 0.343ms where as the peak time from calculation is 0.58ms.

## IX. FUTURE SCOPE

The transient voltage obtained is related to rotor oscillation. The transient torque produced due to transient voltage component results in tremendous rotor oscillation. A further study on rotor oscillation can be done during various fault conditions such as L-G or L-L-G or L-L. Production of transient torques can result in damaging of shafts and produce detrimental effects on bearings. The rotor oscillations can be damped or sustained. Sustained oscillations lead to loss of synchronism. A further study can be done on this basis.

## X. CONCLUSION

The restriking voltage transientas obtained due to circuit breaker switching can result in damaging of breaker contacts. Moreover high restriking voltage can result in delay in arc quenching. Hence, the system is subjected for more time under faulty condition. Resistance switching results in damping of voltage transient enabling faster arc quenching. The phenomenon has been observed here in a hardware model as well as MATLAB simulation. The resistance reduces RRRV and thus reduces burden on the circuit breaker. The resister also increases the breaking capacity of the breaker.

## REFERENCES

[1] J Nagrath and Kothari, "Power System Engineering," Tata McGraw-Hill, New Delhi, 1994

[2] Simulink User's Guide ,The MathWORKS, Natick, M.A.1999

[3] Power System Block Set User'Guide

[4] Ramnarayan Patel, T.S Bhatti and D.P Kothari, "MATLAB/Simulink Based Transient Stability Analysis of Multi Machine Power System", Centre for Energy Studies, Indian Institute of Technology, New Delhi, India

[5] Z. Elechova, M. Smitkova and A.Belan, "Evaluation of Power System Transient Stability and Definition of the Basic Criterion"

[6] Product Documentation of MathWORKS

## AUTHORS

**First Author** – Mahasweta Bhattacharya has recently completed bachelors degree program in electronics engineering in West Bengal University of Technology, India, PH-9038398230. E-mail: mahabh2402@hotmail.com

**Second Author** – Nilanjan Mukherjee is currently pursuing masters degree program in electrical engineering in Indian Institute of Technology, India, PH-9239273299. E-mail: nmnilu6@gmail.com