ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 5, May 2016

# "ANALYSIS THE BEHAVIOUR OF VARIOUS ELECTRICAL LOADS WITH VARIABLE VOLTAGE AND VARIABLE FREQUENCY"

**Mr. Vishwanath Prasad Kurmi**
**M.tech scholar**
**Power System Engineering**
**Dr. C.V. Raman University , Bilaspur(CG)**

**Miss Durga Sharma**
**Assistant professor**
**HOD EE Department**
**Dr. C.V. Raman University Bilaspur(CG)**

**Dr. Dharmendra Kumar Singh**
**Asso. Prof. & (Member of IEI)**
**HOD EEE Department**
**Dr. C.V. Raman University Bilaspur(CG)**

***Abstract:-***When a disturbance occurs in a power system, the value of load power will change in response to the voltage and frequency changes. Step changes in power generation, for example, will induce speed changes in the system frequency and this induces speed changes in any induction motors or other dynamic loads present in the load, and these speed changes will be seen as power changes to the load. Dynamic loads consume 60-70% of the energy from the power system. It is important to have good knowledge about Dynamic loads, because these type of loads draw large reactive currents that can slow voltage recovery after a fault . In this paper the effect of frequency changes *(f)* on *a* various electrical loads real *(P)* and reactive *(Q)* power changes have been modelled. Among the parameters of different electrical loads , the behavior are largely characterized by active power (P) and the reactive power (Q). The model of electrical loads in these frequency and power relations that has been developed can be used to estimate P and Q.

***Key words:-*** Composite Load, Constant Power Load, Constant Impedance Load, Constant Current Load, Induction Motor Load ,Load Modelling, MATLAB/Simulink Power quality, simulation model, MATLAB/Simulink

## I. INTRODUCTION

This paper presents MATLAB/Simulink models used to simulate various power quality disturbances and behavior of loads. The models presented include fault in distribution line, starting of induction motor , and energizing of transformer that are used to simulate various types of voltage sag event. Capacitor bank switching model used to simulate oscillatory transient event, lightning impulse model used to simulate impulsive transient event, nonlinear load models used to simulate triplen harmonic and voltage notching disturbances generated from the load side, and lastly electric arc furnace model used to simulate flicker disturbance are also presented.

## II. METHODOLOGY

The behavior of various electrical loads can be understood by load modeling. Load modeling is important for power system dynamic analyses, including; voltage stability, angle stability and also for grid operation and planning purposes. Accurate load modeling enables engineers to perform a realistic assessment of grid response to the stability concerns. It is also required to avoid overly conservative assumptions for modeling loads that may lead to unnecessary transmission investment . But accurate load modeling is a daunting task because the proportion of motor load to total load is changing with time of day and week , seasons, weather etc. The safe region of operation could be estimated much more accurately if the over all load composition at that time were known with greater certainty.

Because of the importance of load modeling there is a long history of research on this topic. One direction is the survey of equipment owned by consumers and a subsequent prediction of how much is connected at any one time [1],[2]. Another path is to produce simplified aggregate models of a group of loads for offline studies [3],[4]. The approach that probably comes closest to reflecting reality is where measurements are made of the actual load change that occurs when test disturbances are applied [5]. There are two types of field tests. One is a staged test and the other is continuous monitoring. A staged test is used in this research work. An experiment has been setup in the machine laboratory of Dr. C.V. Raman University for the purpose of this research as shown in fig 1.

A load model is a mathematical representation of real and reactive power changes to power system voltage and angle (frequency) changes [6].

*Fig no. 01 experimental setup in the machine laboratory*

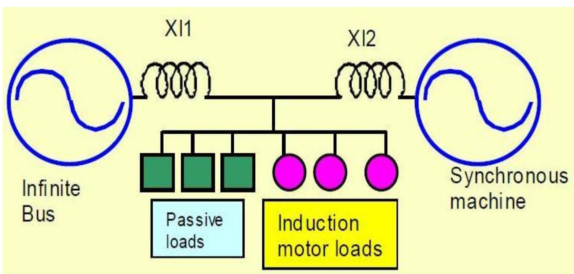


*Fig no. 02 single line diagram of a power system*

For power system analysis, load modeling is very important. It is also important for grid planning and operation [6]. Therefore accurate load modeling is important. Otherwise using overly optimistic models the grid operator will operate the system beyond its capacity which will increase the chances of widespread outages and a pessimistic model will increases the risk of power shortages in an energy deficient region. Ref[6] demonstrates the need for accurate modeling of loads. But accurate load modeling continuously is a difficult task due to several factors such as ;

a. The large number of diverse load components.

b. Ownership and location of load devices in customer facilities not being directly accessible to the electrical utilities.

c. The changing of load composition with time of day and week, seasons, weather.

d. Lack of precise information on the composition of the load.

e. Uncertainties regarding the characteristics of many load components, particularly for large frequency or voltage variations.[1]

Traditionally there are two types of load modelling, static and dynamic [7].

*Static load modelling:* A static model expresses the active and reactive powers at any instant in time as functions of the bus voltage magnitude and frequency at the same instant. Static load model is used both for essentially static load components (e.g. resistive and lighting loads), and as an approximation for dynamic load components [8].

The exponential function of voltage can be expressed in terms of nominal operating point designed by the subscripts o.

$$P_d = P_0 \left(\frac{V}{V_0}\right)^{\alpha} \quad (1)$$

$$Q_d = Q_0 \left(\frac{V}{V_0}\right)^{\beta} \quad (2)$$

There are three types of static load modeling depending on the values of α and β ;

*Constant current model:* When α and β are 1, the static model power varies directly with voltage variation.

*Constant impedance model***:** When α and β are 2, the static load model power varies directly with the square of voltage magnitude.

*Constant power model:* When α and β are zero the static model power is constant in spite of voltage magnitude variations. It's also called a constant MVA model.

*ZIP Model:* Any combination of constant current, constant power and constant impedance model is called the polynomial ZIP model.

$$P_d = P_0 \left[p_1 \left(\frac{V}{V_0}\right)^2 + p_2 \left(\frac{V}{V_0}\right)^1 + p_3\right] \quad (3)$$

$$Q_d = Q_0 \left[q_1 \left(\frac{V}{V_0}\right)^2 + q_2 \left(\frac{V}{V_0}\right)^1 + q_3\right] \quad (4)$$

This model is commonly referred to as ZIP model, as it is composed of Constant impedance(Z) , Constant current(I) and constant power (P) components [7]. The parameters of the models are the coefficients $p_1$ to $p_3$ and $q_1$ to $q_3$ , which define the proportion of each component.

The frequency dependency of the load characteristics is usually represented by multiplying the exponential model or the polynomial model by a factor as follows:

$$P_d = P_0 \left(\frac{V}{V_0}\right)^{\alpha} \left(1 + K_{pf} \Delta f\right) \quad (5)$$

$$Q_d = Q_0 \left(\frac{V}{V_0}\right)^{\beta} \left(1 + K_{qf} \Delta f\right) \quad (6)$$

Or

$$P_d = P_0 \left[p_1 \left(\frac{V}{V_0}\right)^2 + p_2 \left(\frac{V}{V_0}\right)^1 + p_3\right] \left(1 + K_{pf} \Delta f\right) \quad (7)$$

$$Q_d = Q_0 \left[q_1 \left(\frac{V}{V_0}\right)^2 + q_2 \left(\frac{V}{V_0}\right)^1 + q_3\right] \left(1 + K_{qf} \Delta f\right) \quad (8)$$

There are many other types of static load models which have been developed. Conventional static load model scan sometimes adequately represent the characteristics of a residential / commercial feeder load .

Static representation of a load which exhibits dynamic behavior scan give quite a misleading result[4]. As a result of this, dynamic load modeling is important for predicting the characteristics of load which have their own dynamic responses to voltage and frequency.

*Dynamic load modeling:* Difference or differential equations can be used to represent dynamic loads.

$$T_p \dot{P}_d + P_d = P_s(V) + K_p(V)\dot{V} \quad (9)$$

$$T_p \dot{Q}_d + P_d = Q_s(V) + K_q(V)\dot{V} \quad (10)$$

Static and dynamic load modeling can give a similar result for studies on security limits but for large excursions of frequency and voltage fluctuation the difference between two models can be significant. Hence the type of load modeling depends on what types of system analysis are being studied [8]. Additionally, rotor angle stability, voltage stability , induction motor stability, cold-load pickup and dynamic over-supply of voltage call for unique load modeling requirements. All these terms are described in Ref[1]. For this research work , modeling has been done for general purpose studies, which can be used in all types of stability problems.

*Composite static and dynamic load modeling:* A composite load model which allows the representation of wide range of characteristics exhibited by the various load components as shown in fig 3.

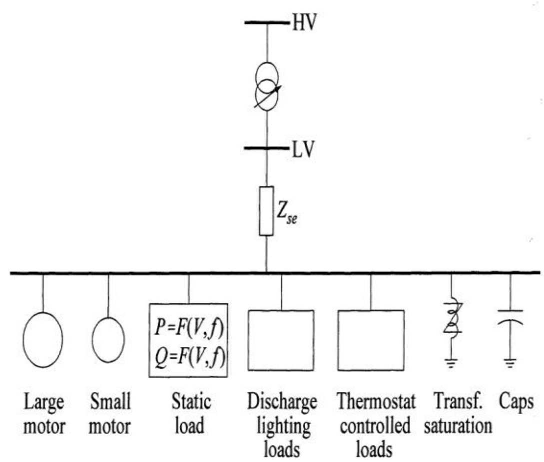


*Fig 3. Composite static and dynamic load model[27]*

## III. SIMULINK/MATLAB MODEL

*Measurement based analysis of composite load :* A simulink / MATLAB model has developed for composite (static and dynamic) load model and analyzed the changes in P and Q with change in voltage and frequency.

Figure 04. showing the simulation diagram of composite lode (static and dynamic loads) which is modeled in MATLAB.

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 5, May 2016

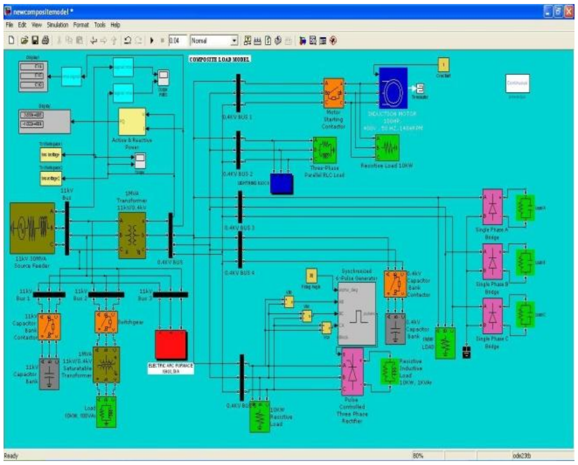

***Fig no. 04*** *MATLB/Simulink model for composite load*

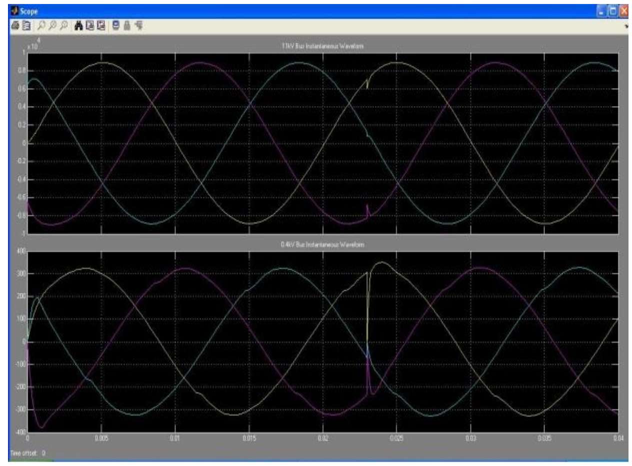

*Fig no. 05* voltage waveform of 11kv bus and 0.4 kv bus.

***System parameters:***

***TABLE I***

| Sl. No. | Block name | Parameter details |
|---|---|---|
| 1 | Source Feeder | 11kV 30MVA |
| 2 | Bus bar | 11KV and 0.4KV |
| 3 | Saturatable Transformer | 11kV/0.4kV 1MVA |
| 4 | Capacitor Bank | 11Kv 10KVAr |
| 5 | Capacitor Bank | 0.4Kv 40KVAr |
| 6 | Electric arc furnace | 19KW, 5KA |
| 7 | Single phase non linear load | 10kW |
| 8 | Induction motor | 100 HP, 400 V , 50 HZ, 1484RPM |

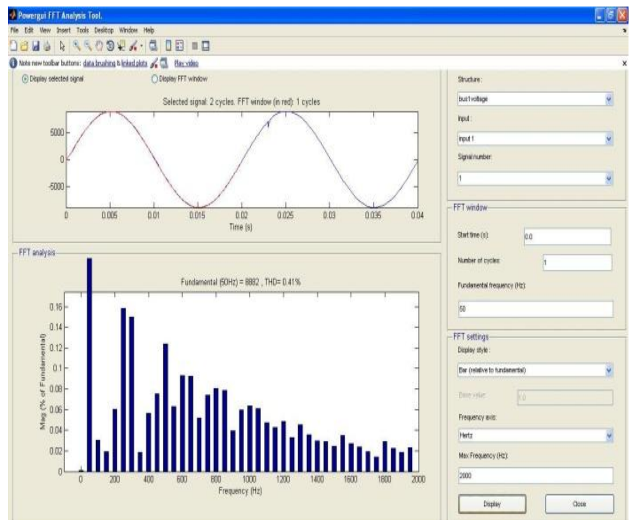

*Fig no. 06 FFT analysis of 11Kv bus voltage*

*Harmonic analysis:* In an ideal power system voltage and current waveforms are purely sinusoidal. In practice, non sinusoidal current results when the current flowing through the load is non linear with the applied voltage. Non linear loads are the main factors for the waveform distortion from the sine wave and this is the cause of harmonics.

Composite load creates the power quality problems in power system. Fig 5 shows the distorted voltage waveform of 11kv bus and 0.4 kv bus.

The FFT analysis of supply voltage is shown in the figure 6 and figure 7. The THD of 11KV and 0.4KV bus voltage is 0.41% and 4.93% respectively as shown in fig no 06 and 07.

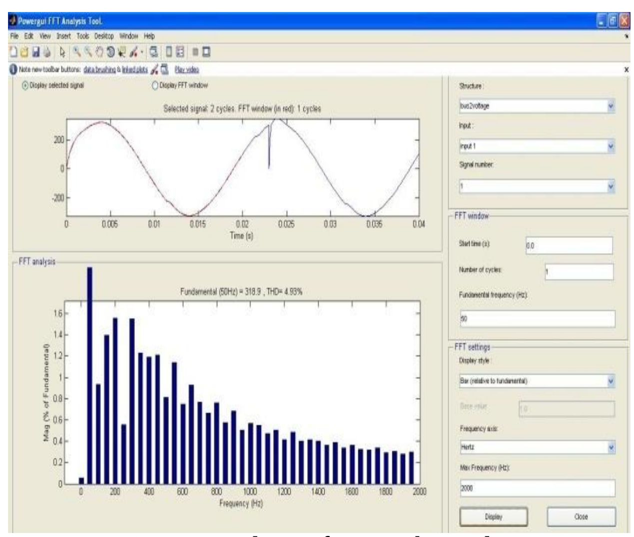

Fig no. 07 FFT analysis of 0.4KV bus voltage

ISSN: 2278 – 7798
International Journal of Science, Engineering and Technology Research (IJSETR)
Volume 5, Issue 5, May 2016

## IV. SIMULATION RESULTS

The composite load connected to the source feeder draws non sinusoidal waveform from the supply mains. The variation of active (P) and reactive power(Q) are analyzed by cftool in matlab. A graph has plotted for P vs V , Q vs V and Q vs f as shown in fig no 8, 9and 10 respectively.

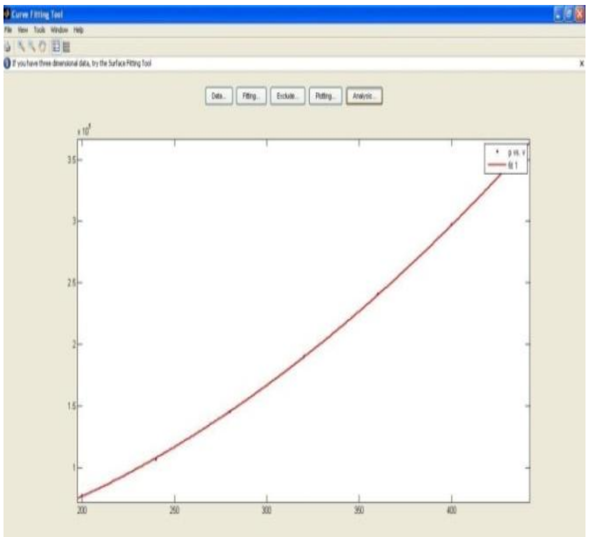

*fig no. 08 Variation of active power with variation of voltage*

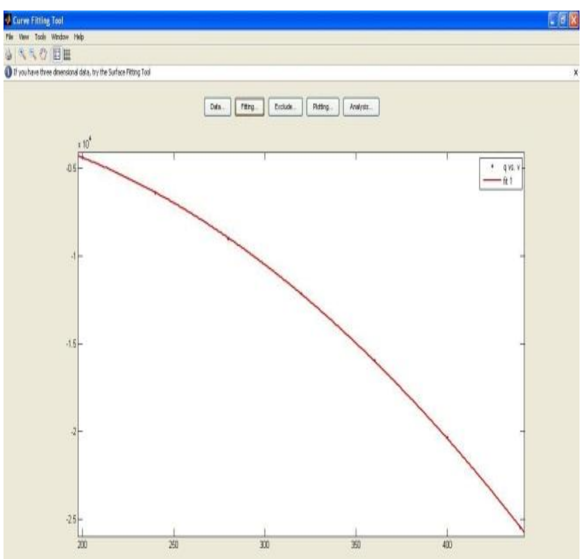

*Fig no. 09 Variation of reactive power with variation of voltage*

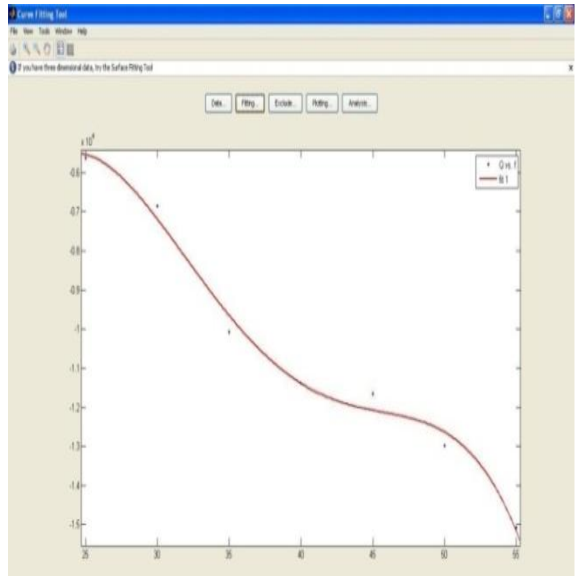

*Fig no. 10 Variation of reactive power with variation in frequency*

## V. CONCLUSION

The simulation approach provides the researcher the flexibility to create power system models to simulate power quality disturbance by connecting various functional building blocks in the simulation environment. It gives an insight on how power quality disturbance propagates and behaves within the simulated power system model. The limitation of the simulation approach is its dependency on the capability of the chosen simulation software, basic knowledge of power quality and the simulation software, and the availability of power system building blocks required to build the power system model to simulate the intended power quality disturbance. Based on field measurements the identification of a load model can be carried out. The both static, and dynamic model of loads can be described in this work as well as combined ones. Load modeling is a challenge for today`s engineers. It`s variety and not constant nature makes them hard to simulate. There have been a lot of studies on load modeling in order to represent it with maximum accuracy. There are many simulation software that allows to simulate power system loads basing. i.e. on polynomial and exponential load model representation. The only way is that fit a model of a suitable behavior dynamic load by data, which voltages and frequency dependence of a composite load on the transmission line. It is more practical and realistic than the mathematic.

REFERENCES

[1] Chia –Jen Lin, Yung-Tien Chen, " Dynamic load models in power system using measurement approach", IEEE transaction on power system vol. 8, pp 309-315, 1993.

[2] C chen , T Wu "the applications of load models in electrical appliances to distribution system analysis" , IEEE transaction on power system vol. 8, No. 01, 1995.

[3] B khodabakhchain , G-Tong, "Modelling a mixed residential – commercial load for simulations involving large disturbances" IEEE transaction on power system vol. 12, no.02, 1997.

[4] I.A.Hiskens, J.V.Milanovic, "load modeling in studies of power system damping" IEEE transaction on power system vol. 10, No. 04, 1995.

[5] D karlsson, P.Ju, " non-linear dynamic load modeling :model and parameter estimation" IEEE transaction on power system vol. 11, pp 1689-1697, 1996. [6] Performance , task force on load representation for dynamic "load representation for dynamic performance analysis " IEEE transaction on power system vol. 8, pp 472-482,1993.

[7] Kundur , Prabha' "power system stability and control" 1994.

[8] X. Lai, Y, "Static and dynamic approaches for voltage stability" EUROPEAN TRANSECTION ON ELECTRICAL POWER, vol. 16, pp 276-296, 2006