Dynamic Performance Estimation of DFIG wind turbine under Balance /Unbalance grid fault condition

By

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CERTIFICATE

This is to certify that the thesis report entitled “DYNAMIC PERFORMANCE OF DFIG WIND TURBINE UNDER BALANCE/UNBALANCE GRID FAULT CONDITION” submitted by Mr. TANUJ KUMAR MISHRA in partial fulfillment of the requirements for the award of Master of Technology degree in Electrical Engineering with specialization in “Power Control and Drives” during session 2008-2009 at National Institute of Technology, Rourkela (Deemed University) and is an authentic work by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university/institute for the award of any degree.

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Tanuj Mishra

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Contents

INDUCTION MACHINE

List of Figures

NOMENCLATURE

v_{ds} , v_{qs}	Stator *d* and *q* winding voltage.
i_{ds} , i_{qs}	Stator *d* and *q* winding current.
v_{dr} , v_{qr}	Rotor *d* and *q* winding voltage.
i_{dr} , i_{qr}	Rotor *d* and *q* winding current.
ψ_{ds} , ψ_{qs}	Stator *d* and *q* winding flux linkage.
ψ_{dr} , ψ_{qr}	Rotor *d* and *q* winding flux linkage
T_e	Electromagnetic torque.
T_m	Mechanical torque
Q_s	Stator reactive power.
P_s	Stator active power
L_m	Generator magnetizing inductance.
L_s , L_r	Stator and rotor per phase winding inductance.
L_{ls} , L_{lr}	Stator and rotor per phase leakage inductance.
R_s , R_r	Stator and rotor per phase winding resistance.
p	Number of generator poles.
H	System moment of inertia.
B	System frictional constant.
ω	Synchronous rotational speed (50 Hz).
ω_r	Rotor mechanical speed.
ω_b	Base speed

ABSTRACT

The global electrical energy consumption is rising and there is a steady increase in the demand of power generation. So, in addition to conventional power generation units a large no. of renewable energy units are being integrated into the power system. A wind electrical generation system is the most cost competitive, environmentally clean and safe out of all the renewable energy sources. The recent evolution of power semiconductors and variable frequency drive technology has aided the acceptance of variable speed generation systems.

Slip ring induction motor in the variable speed double fed induction generator mode is largely used in wind turbine generation technology. Therefore, a detailed model of induction generator is presented in the thesis. Then the induction generator is operated at different operating conditions and the results are presented in the thesis. A hardware set up is build up to estimate the different circuit parameter under different operating conditions. Speed, torque, Active and reactive power estimation are proposed in the thesis with the help of hardware set-up. Because these are the controllable parameter and they determine the machine performance. So, by estimating these parameter our future aim is to manipulate those parameter and to design a closed loop controller for DFIG. This study is relevant as DFIG-wind turbines are an integrated part of Distributed generation system. Any abnormalities associated with grid are going to affect the system performance considerably. Taking this into account, the performance of double fed induction generator (DFIG) variable speed wind turbine under network fault or under dynamic loading is studied. The significant result of the analysis is also shown and being compared with the existing literature to validate the approach.

Signature of student | Signature of supervisor

Dr.Sharmili Das

SYNOPSIS

- **In my thesis wind power flow through turbine connect to the shaft of the induction motor.stator of the IM is connected to the grid and rotor side connected to the power electronics control circuit.**
- **The power electronics circuit devided into two part a)rotorside converter control b)grid side converter control.Both case PWM tethnic is used.**
- **Both controller connected to the two reference current both side.**
- **Grid reference active and reative power also connected in grie side controller.**
- **Grid operation control also connected to the reference active and reative power with wind turbine level and wind turbine control level.**
- **Objectives-:before going to control, it is important to fault generation in grid side.Total setup taking in to the laboratory (machine lab) in the figure.a dc motor induction motor couplingset taking in the place of wind turbine and induction motor .The speed of the induction motor can very by varying the speed of the dc motor.The speed of the dc motor can be control by armature and field control method.Here dc motor gives variable speed just like variable wind speed.The speed can be controlled by changing the resistance of reostart connected in the armature and field of the DCmotor.In the other hand the rotor side of the IM is short circuited just like squrallelcase induction motor.We can connected the controller in the rotor side.Some times we can connected crow bar for protection.Here we have only detect the faults in various conditions.**

Sudden change of load inIG and supply: Load box used as grid where bulb load is given it is three phase load.If suddenly change of load in load box and detected in standard resister we get the result.both IG and supply given the power to the loadmeans suppyly is not dis connected

current due to unbalance loading in IG and supply:Here **three phase balance load is given,we have to change the the load of one phase less or more as compare to other two phase.Then taking the switching graph .**

WIND TURBINE USING DFIG, INDUCTION GENERATOR AND GRID FAULT DETECTION

Control strategy

Practical strategy

Voltage current waveform

sudden change of load

Creatation of fault and wave form

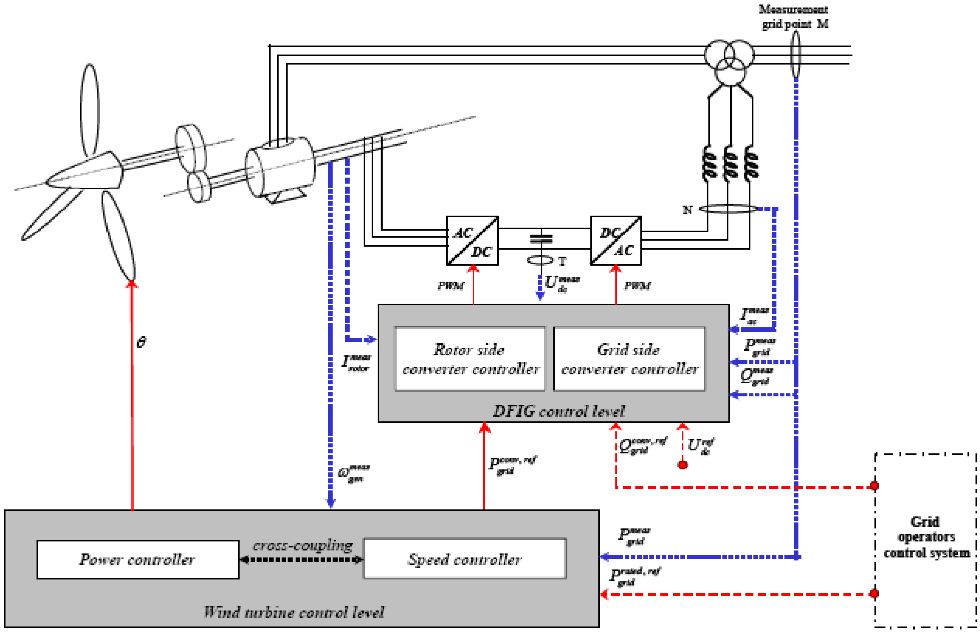


Figure 43: Overall control system of variable speed wind turbine with doubly-fed induction generator.

1.1 OVER ALL CONTROL OF WIND TURBINE USING DFIG

The increased interest in renewable energy production together with higher and higher demand from the energy distribution companies (TSO) regarding grid energy injection and grid support in case of a failure raises new challenges in terms of control for wind turbine (WT) systems.

The modern WT should be able to stay connected to the grid for a period specified by the TSO even when the grid voltage has dropped to a very low value (10% of its nominal value is a commonly specified minimum value). In a DFIG WT, where the stator of the generator is directly coupled to the grid, a failure (voltage sag) will be seen by the generator. These will threat the power electronic equipment on the rotor side which should be protected by some means.

The wind turbine control generates two control signals:

• The converter reference active power - is the set point for the active power signal for the DFIG control level. It is generated based on the measured generator speed and the measured grid power in the measurement grid point *M*. For example, when the wind speed is less than the rated wind speed, the wind turbine control level generates the converter reference active power by adjusting the generator speed in such a way that the turbine captures the maximum power.

The pitch angle θ - is delivered directly to the wind turbine blades. The pitch angle actuator system is implemented as a part of the power controller. It is generated based on the measured grid power and the reference rated active power . The reference rated active power signal is normally the nominal power of the wind turbine Similarly to Q , can be imposed in special situations by the grid operators control system to a power value less then the nominal (rated) power of the wind turbine. The present work considers the case when is the nominal (rated) power of the wind turbine.

1.11 The overall control system of a variable speed wind turbine with DFIG

The control system of a variable speed wind turbine with DFIG has as goals to control the reactive power interchanged between the generator and the grid and the active power drawn from the wind turbine in order to track the wind turbine optimum operation point or to limit the power in the case of high wind speeds. Each wind turbine system contains subsystems (aerodynamical, echanical,electrical) with different ranges of time constants, i.e. the electrical dynamics are typically much faster than the mechanical. This difference in time constants becomes even bigger in the case of a variable speed wind turbine, due to the presence of the power electronics. Such more complicated electrical system requires a more sophisticated control system too. shows the overall control system of a variable speed DFIG wind turbine. Two control levels which have different bandwidths and are strongly connected to each other, can be distinguished in the overall control system: •1) Doubly-fed induction generator control (control of active and reactive power)2)• Wind turbine control.

The DFIG control encompasses the electrical control of the power converters and of the doubly-fed induction generator. Since this controller is an electric one, it works very fast. The DFIG control level has as goal to control the active and reactive power of the wind turbine independently. The DFIG control contains two decoupled control channels: one for the rotor side converter and one for the grid side converter .

As the pulse-width modulation factor *PWM* is the control variable of the converter, each of these control channels generates a pulse-width modulation factor *PWM,* for the respective converter. This control variable is a complex number and therefore can control simultaneously two variables, such as the magnitude and phase angle of the rotor induced voltage. For example, for a predefined DC voltage and a control variable (pulsewidth modulation factor *PWM*), the line-to-line AC-voltage is determined . On the other hand, the wind turbine control is a control with slow dynamic responses. The wind turbine control contains two cross-coupled controllers: a speed controller and a power limitation controller. It supervises both the pitch angle actuator system of the wind turbine and the active power setpoint of the DFIG control level. It thus provides both a reference pitch angle θref directly to the pitch actuator and a converter reference power signal for the measurement grid point M to the DFIG control.

Different line styles are used to provide a quick overview of the signals of the overall control system in the figure

• double-dotted lines mark the measured signals.

• single dotted-lines reveal reference (setpoint) signals

• solid lines reveal the output signals from the controllers Notice that the overall control system requires information on different measured electrical signals: the active and reactive power (measured in the measurement grid point M).

The DFIG control level has three reference input signals:

• The converter reference active power in the measurement grid point *M*. This information is delivered by the wind turbine control level.

• The converter reference reactive power in the measurement grid point *M*. This reference can be extraordinarily imposed by the grid operators (based for example on a certain dispatch control). For example in the case of a weak grid or a grid fault situation, the DFIG can have the extra task to generate reactive power to support the grid voltage.

• The reference DC- voltage *U* is a value strictly connected to the size of the converter, the stator-rotor voltage ratio and the modulation factor

1. *Squirrel cage induction generator model* (asynchronous machineblock model) – has the mechanical power of the wind turbine as primer mover input. An additional rotor resistance can be inserted if it is necessary. The outputs are the generator speed and the electrical power. In the load flow calculation,used in the initialisation process of the system, the information on the generators active power has to be specified.

2. *Doubly-fed induction generator model* (*ElmAsmsc* slip controlled asynchronous machine block model) – has as inputs the mechanical power of the wind turbine, the pulse width modulation factors *Pmd, Pmq* and the additional rotor resistance. As outputs, besides the

speed and the active power, the rotor currents, the stator flux and the mechanical angle of the rotor can be delivered. In the load flow calculation, the active power for the stator, the reactive power and the slip have to be specified. Internally, the corresponding modulation factors of the converter are calculated and together with power balance between the AC and DC side of the converter, DC voltage and DC current are obtained.

1.2 Squirrel cage induction generator (SCIG)

uses different equivalent circuits to define the parameters in the induction generator model, as illustrated in Figure 3. It consists of a general model for the stator, which can be combined with three different rotor models,depending on the type of the generator. The model is thus basically a classical induction machine model including a slip dependent rotor impedance .

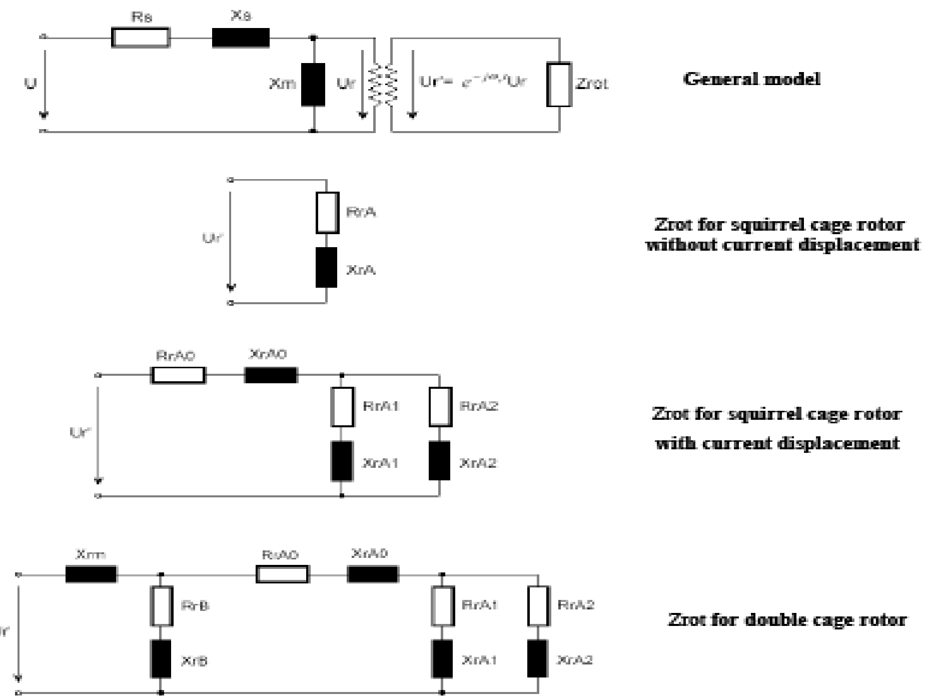


Figure 3: Squirrel cage induction generator diagram with the different definitions for the rotor impedance Zrot.

The model is characterized by the stator winding resistance *Rs*, the stator leakage reactance *Xs*, the magnetizing reactance *Xm* and the rotor impedance *Zrot*.The rotor impedance *Zrot* is frequency dependent and allows therefore the modeling over a wide speed/slip range. The rotor impedance can be approximated by parallel R-L elements. Different rotor circuit designs, depending on the rotor geometry, can thus be modeled by selecting a specific rotor impedance *Zrot*.

Three different squirrel cage rotor types, as illustrated in Figure 3, can be used:

- Squirrel cage rotor without current displacement
- Squirrel cage rotor with current displacement
- Double cage rotor

. The input parameters of the generator can be entered either bydirectlyspecifying the resistances and reactances of the equivalent circuit diagrams (if they are known e.g. from tests or other simulation programs) or by specifying characteristic points on the slip-torque and slip-current characteristic of the generator.When the electrical parameters are not available, they are automatically calculated from the nominal operation point and slip-torque/slip-current characteristics the nominal operation point is specified by the rated mechanical power, the rated power factor, the efficiency at nominal operation and the nominal speed.

The dynamic model of the induction generator uses the steady state parameters defined in the equivalent diagram depicted in Figure

$$u_s = R_s i_s + j\,\omega_{syn}\psi_s + \frac{d\psi_s}{dt}$$
$$0 = R_r i_r + j\,(\omega_{syn} - \omega_r)\psi_r + \frac{d\psi_r}{dt} \qquad (1)$$

where u, i, and ψ are space vectors for the voltage, current and flux, respectively.ωsyn is the synchronous speed, while ωr is the angular speed of the rotor.As the rotor is short-circuited in the squirrel-cage induction generator, therotor voltage is set to zero. The voltage equations are used in in per unit quantities, as follows:

$$\underline{u}_s = \underline{R}_s \underline{i}_s + j\frac{\omega_{syn}}{\omega_n}\underline{\psi}_s + \frac{1}{\omega_n}\frac{d\underline{\psi}_s}{dt}$$
$$0 = \underline{R}_r \underline{i}_r + j\frac{(\omega_{syn} - \omega_r)}{\omega_n}\underline{\psi}_r + \frac{1}{\omega_n}\frac{d\underline{\psi}_r}{dt} \qquad (2)$$

where ω_n is the nominal electrical frequency of the network. As mentioned before, provides models with different detailing levels. Depending on the goal of the analysis, it is possible to select the models of an appropriate detailing level, by choosing the type of simulation method.

For stability analysis, power quality and control issues, RMS simulations are used. RMS simulations are based on simplified electromechanical transient models. In the case of induction generators, the RMS simulation is using a third order generator model, where the stator transients are neglected. For the analysis of the wind turbine’s behavior during grid faults, electromagnetic transient EMT simulations of instantaneous values are used. For this purpose, models of higher detailing level e.g. a fifth order generator model are used.

The generator inertia is modeled inside the built-in induction machine model. The generator inertia is specified in the form of an acceleration time constant in the induction generator type.The dynamic model of the induction generator is completed by the mechanical equation:

$$J\,\dot{\omega}_r = T_e - T_m \qquad (3)$$

where *J* is generator inertia, *Te* is the electrical torque, *Tm* is the mechanical torque. The mechanical equation can be rated to the nominal torque: and thus the acceleration time constant *Tag* can be expressed as:

$$T_n = P_n / \left[\omega_n (1 - s_n)\right] \qquad (4)$$

where ω*n* is the nominal electrical frequency of the network and *sn* is the nominal slip

$$T_{ag} = \frac{J\,(1 - s_n)\,\omega_n^2}{P_n} \qquad (5)$$

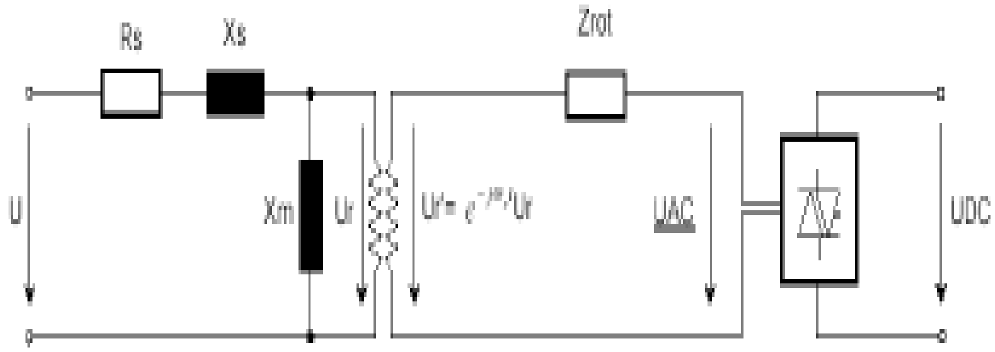


Figure 4: Doubly-fed induction machine with rotor side converter.

1.3 Power converters

It provides models for different power converters such as: rectifiers/inverters, PWM converters,. They are briefly described below.

Rectifier/Inverter

The rectifier/inverter model is used to create DC power links, or for building power electronic devices such as variable speed drives,The rectifier and inverter models allow modelling of different types of frequency converters. For example, in the doubly-fed induction generator concept,the rotor circuit is connected to the grid through two PWM convertersworking back-to-back.

PWM converter

The power converters used in wind turbines are usually realised by self commutated pulse-width modulated circuits – see Figure6

Figure

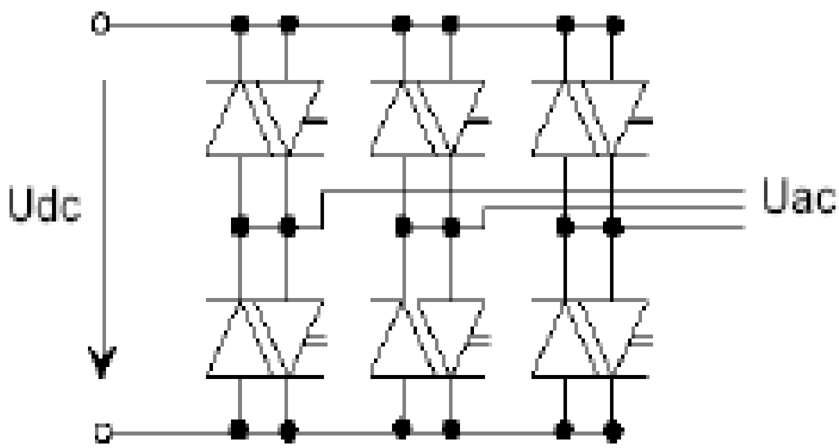


Figure 6: Generic PWM converter model.

These circuits are built by six valves with turn-off capability and six antiparallel diodes. The valves are typically realised by IGBTs (insulated gate bipolar transistors) because they allow for higher switching frequencies than classical GTOs.The general model of the PWM converter, that usually operated as a voltage source converter,:

1.31 DIFERENT CONTROL MODEL

• *Udc-Q mode*: regulates the dc-voltage and the reactive power. This mode is typical for the grid-side converter of a doubly fed induction machine.

• *Uac-phi mode*: regulates the ac-voltage magnitude and angle on the DC side. This mode is typical for variable speed drive applications, when the converter drives an induction machine at the AC side.

• *P-Q mode*: regulates the active and reactive power.

1.4 Softstarter

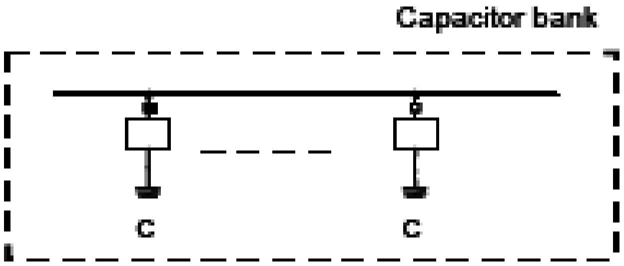
The softstarter is a simple and cheap power electric component, used in the fixed speed wind turbine during connection or disconnection to the grid of its generator. The softstarter's function is to reduce the in-rush current and thereby limit the disturbances to the grid. Without a softstarter, the in-rush current can be up to 7-8 times the rated current, which can cause severe voltage disturbance

in the grid.The softstarter contains two thyristors, as commutation devices in each phase. They are connected in anti-parallel for each phase. The smooth connection of the generator to the grid, during a predefined number of grid periods, is done by adjusting the firing angle (α) of the thyristors. The relationship between the firing angle (α) and the resulting amplification of the soft starter is highly non-linear and depends additionally on the power factor of the connected element.After in-rush, the thyristors are bypassed in order to reduce the losses of the overall system.The soft starter model in a dqo model, considering one phase and an RL source. There are many configurations of soft starters, which fed an induction machine, as for example: a) star connection b) delta connection and c) branch-delta connection. In wind turbine applications mainly the delta connection for the induction machine is used because the current rating of the stator windings can be reduced, and the third harmonic in the line currents is eliminated in this case. In delta branch connection, the soft starter is not in series to the induction generator lines, but it is built inside the delta of the generator, reducing thus the power rating of the thyristors. As in, the soft starter and the generator blocks are two independent components, it is not possible directly to model the generator with delta branch softstarter. However, the delta branch connection could be possibly equivalent with an ideal delta/star transformer in series with the softstarter and a star connected induction generator.

Capacitor bank

The capacitor bank is an electrical component, which is supplying reactive power (i.e. to the induction generators or to the grid). Thus the reactive power absorbed by the generator from the grid is reduced.The general compensation device is modelled by a series connection of a capacitor *C*, a reactor *L* and a resistance *R*. The user can choose between different types of shunt, e.g.: *C, R-L* or *R-L-C*. The capacitor can be connected in a star or delta configuration.

To represent a parallel connection of capacitors, several compensators in parallel must be connected to the same busbar, as illustrated in Figure 8.



CAPACITOR BANK

The capacitor bank system is combinations of shunt capacitors, which can be switched on and off individually, depending on the load situation in response to changes in reactive power demands.

1.5 Transformer

provides model blocks both for 2-windings transformer and for 3-windings transformer. The two/three winding transformer is a two/three –port element connecting two/three cubicles, respectively, in the power system. Both transformers include manual and automatic tap changers with voltage, active power or reactive power control. In the following, the model of the 3- windings transformer is briefly illustrated. The representation of the positive sequence equivalent diagram is shown in Figure 9 and includes a generalised tap-changer model. The magnetisation current may be chosen to be linear or piecewise linear, which is defined with a knee-current, a linear current and a saturated current. The zero sequence equivalent models for three common winding connections are illustrated.

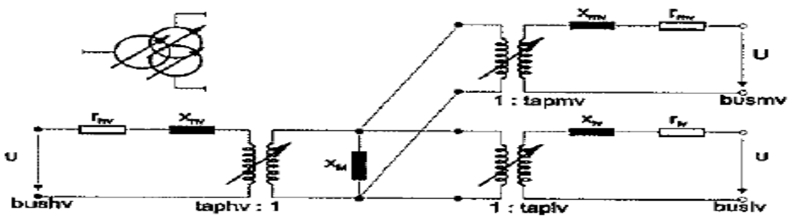


Figure 9: Positive sequence - three windings transformer equivalent model. Source: DIgSILENT Power Factory Manual. Version 12.0 (DIgSILENT GmbH,2001).

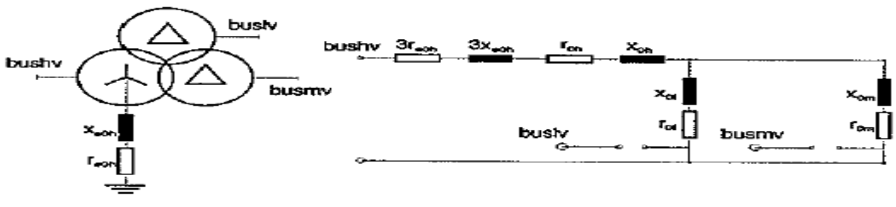


Figure 10: Zero sequence - grounded star/delta/delta connection. Source: DIgSILENT Power Factory Manual. Version 12.0 (DIgSILENT GmbH,2001).

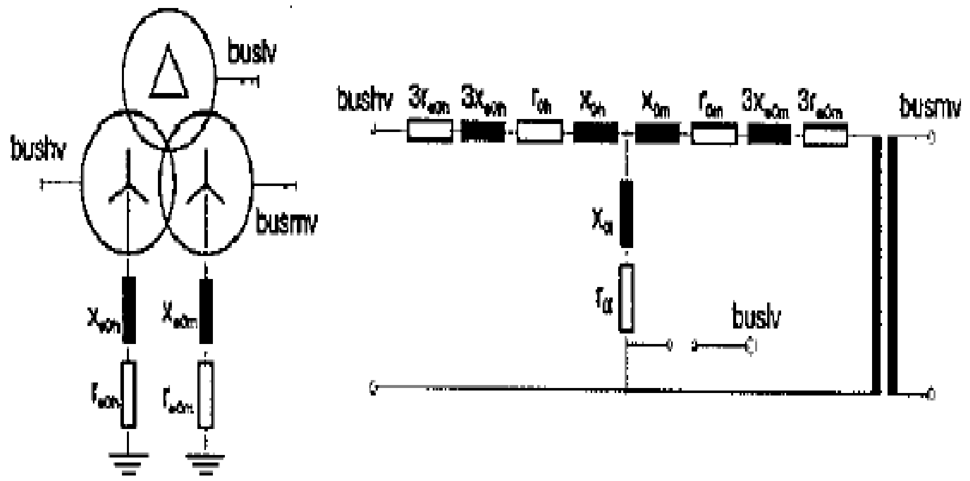


Figure 11: Zero sequence - grounded star/grounded star/delta connection. Source: DIgSILENT Power Factory Manual. Version 12. (DIgSILENT GmbH,2001).

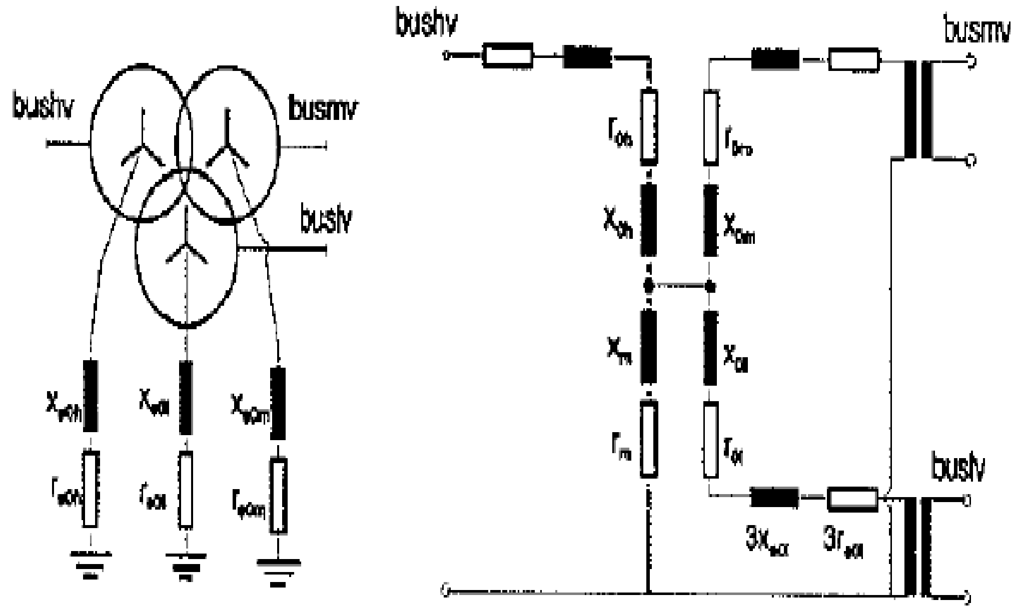


Figure 12: Zero sequence - grounded star/grounded star/ grounded star connection. DIgSILENT Power Factory Manual. Version 12.0 (DIgSILENT GmbH,2001).

1.6 DAMPING

In normal operation, the active power set-point *grid ref P* for the rotor side converter is defined by themaximum power tracking point (MPT) look-up table as function of the optimal generator speed ,. In case of a grid fault, the active power setpoint *grid ref P* is defined as the output of a damping controller, which has as task to damp the torsional oscillations, which are excited in the drive train due to the grid fault. When a fault is detected, the definition of the active power set-point *grid ref P* is switched between the normal operation definition (i.e. MPT) and the fault operation definition (damping controller).

As illustrated in the PI damping controller produces the active power reference signal for the rotor side converter control, based on the deviation between the actual generator speed and its reference [6]. The speed reference is defined by the optimal speed curve at the incoming wind. The damping controller is tuned to damp actively the torsional oscillations excited at a grid fault in the drive train system. The pitch control system, illustrated in , is not able to damp the torsional oscillations, because of several delay mechanisms in the pitch [14]. In contrast to this, the damping controller acting on the fast power converter control is able to damp the fast oscillations in the generator speed.[1]]

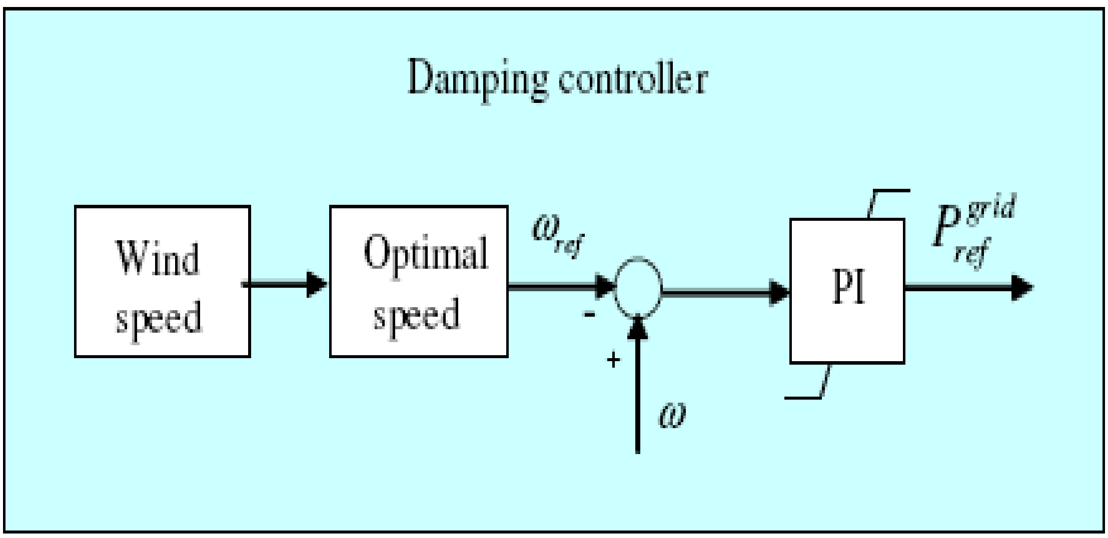
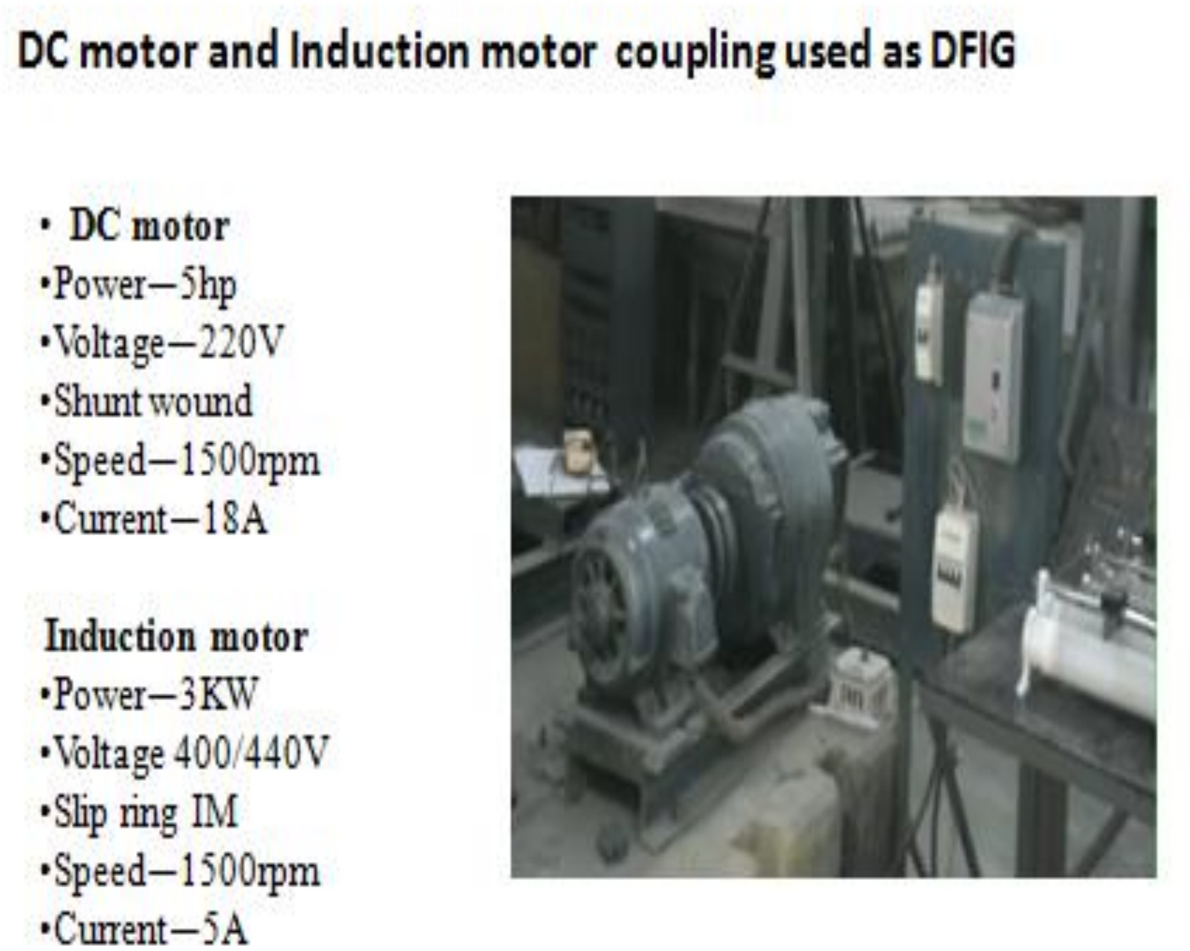


Fig 4: Damping controller

1.7 PROTECTION SYSTEM

The use of the partial-scale converter to the generator’s rotor makes the DFIG wind turbine concept attractive from an economical point of view. However,on the other hand, this converter arrangement requires an advanced protection system, as it is very sensitive to disturbances on the grid. Without any protection system, the concern in DFIG is usually the fact that large disturbances lead to large fault currents in the stator due to the direct connection of its stator to the grid.Because of the magnetic coupling between the stator and the rotor and of the laws of flux conservation, the stator disturbance is further transmitted to the rotor. The results are both high rotor currents and voltages during the grid faults. Furthermore,when the grid voltage drops in the fault moment, the grid side converter is not able to transfer the power from the rotor side converter further to the grid and therefore the additional energy goes into charging the dc bus capacitor and thus the dc bus voltage rises rapidly. It is therefore necessary to protect the converter against overcurrents, the rotor of the generator against overvoltages and the dclink against overvoltages. The protection system monitors usually different signals, such as the rotor current, the dc-link voltage and when at least one of the monitored signals exceeds its respective relay settings, the protection is activated. A simple protection method of the DFIG under grid faults is to short circuit the rotor through a crowbar, an external rotor impedance. The function of the crowbar is to limit the rotor current. When the crowbar is triggered, the rotor side converter is disabled and bypassed, and therefore the independent controllability of active and reactive power gets unfortunately lost.[1].



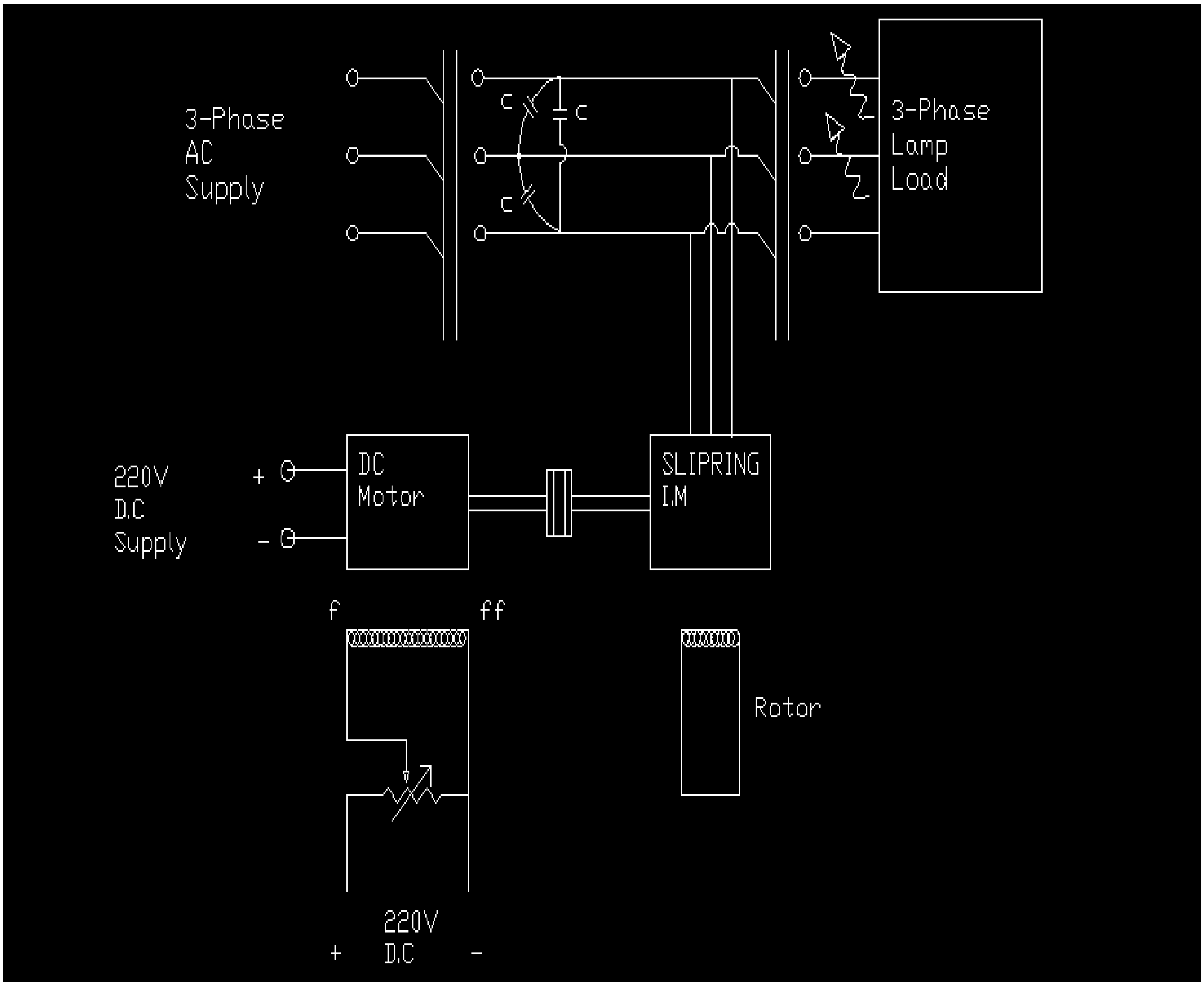
1.8 Fig We have taking a laboratory setup of DC motor induction motor set. DC motor behaving

as wind turbine its speed can be changed by change the the resistance of fields as well as armature. The synchronous speed of the IM is1500rpm.The speed of the DC motor vary maximum upto3000rpm.above the synchronous speed t he IM behave as Induction Generator. It means when wind speed above the the synchrous speed the IM behave as Induction Generator, It gives power to the grid.he rotor side is short circuited just like squirrel cage IM.

Laboratory setup

1.9Fig Experimentally induction motor dc motor set connected with capacitors bank. Load box used as grid it was connected with a switch,it has three phase bulbs load connection is balance loading but we have to make it unbalanced by changing the switching action of the bulb load Two reostart is connected in the DC motor side, they are used for field and armature control of DC motor. The speed of of DC motor increase above the synchronous speed. Hence IM is coupled with it ,it moves above the synchronous speed. This time induction motor behave as induction generator. Power flow takes place from IM to grid/loadbox.

Circuit diagram



1.10Fig This is the circuit diagram for IM working as a induction generator. DC motor IM coupling set moves the induction motor above the synchronous speed by changing the field resistance of DC motor. Rotor is short circuited so this induction motor behave single fed induction motor. Lamp load placed in the place of Grid, fault in grid is equivalent to fault creating in 3-phase lamp load. Capacitor Bank used for storage the power in switching operation.

1.11 DFIG USED IN WIND TURBIN

Wind turbine generators have become extensively used in many countries to generate power to the grid. Many types of generators may be used with the turbine to supply the energy. The doubly-fed induction generator (DFIG) is widely used with off-shore wind turbines, and because of the difficulty in accessing such turbines, health monitoring and fault diagnosis become important to help schedule maintenance and minimize unforeseen failure. A DFIG consists of a wound-rotor induction machine, back-to-back PWM converters, three-phase filter and a three-phase transformer. As shown in Fig. 1, the stator is connected directly to the grid whereas the rotor is connected to the grid via the back-to-back PWM converters, filter and transformer. Compared with other parts, the back-to-back converters are the least reliable parts of this generator. The faults that can occur in a conventional induction motor drive, as listed in [2], can also occur in this generator.

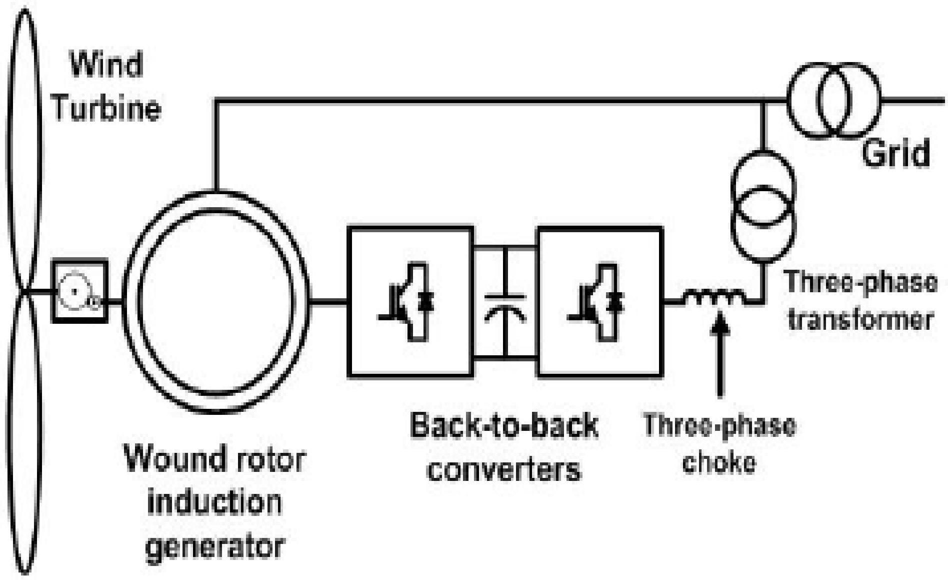


Fig.1. The topology of a doubly-fed induction generator used with a wind turbine

This paper focuses on open switch faults occurring in either the machine-side or line-side converter and presents the effects of open switch faults on doubly-fed induction generator variables. The existing methods which have been proposed to detect open switch faults for electrical drives are then briefly discussed as well as the advantages and drawbacks of each method when applied to the DFIG. This paper presents a new method to detect open-switch faults on the DFIG which overcomes the problems of the existing methods. The experimental setup and simulation method are described in detail.

1.12 PROTECTION SYSTEM

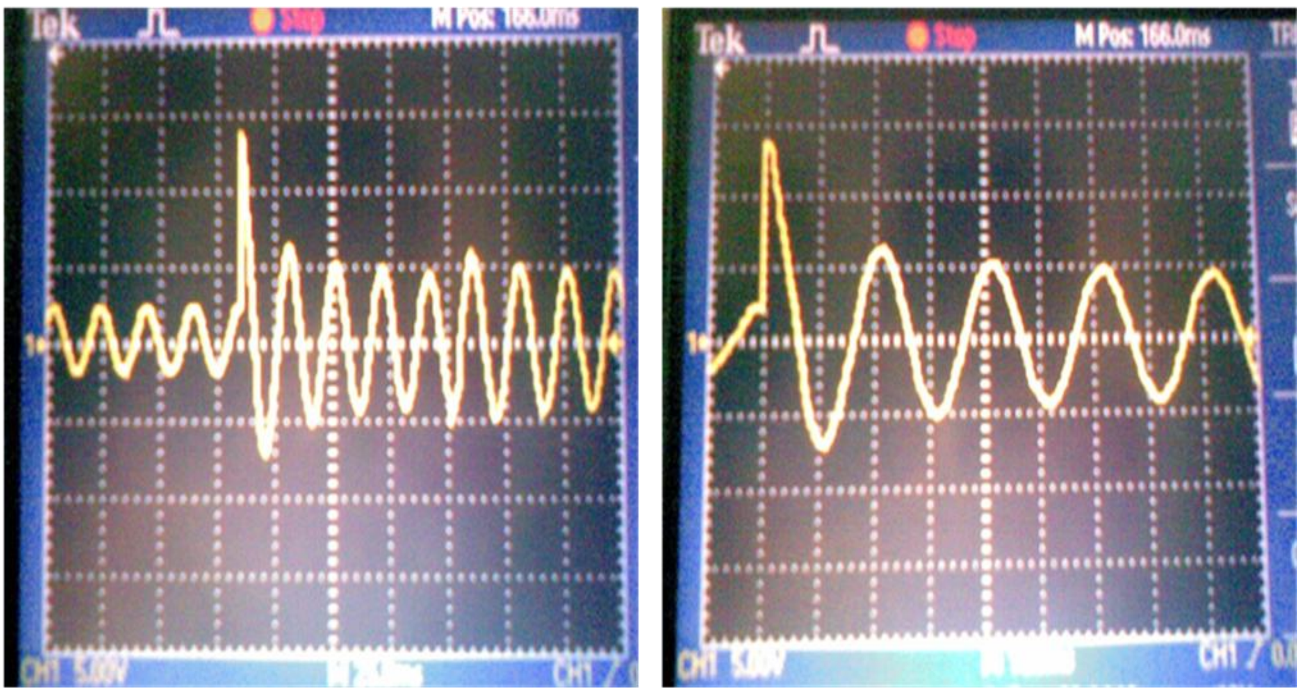
The increased interest in renewable energy production together with higher and higher demand from the energy distribution companies (TSO) regarding grid energy injection and grid support in case of a failure raises new challenges in terms of control for wind turbine (WT) systems.

The modern WT should be able to stay connected to the grid for a period specified by the TSO even when the grid voltage has dropped to a very low value (10% of its nominal value is a commonly specified minimum value). In a DFIG WT, where the stator of the generator is directly coupled to the grid, a failure (voltage sag) will be seen by the generator. These will threat the power electronic equipment on the rotor side which should be protected by some means. A common protection circuit is a crow bar (CB) which is connected in parallel with the rotor side inverter. variable speed range, in case of grid faults it might not be possible to achieve the desired rotor voltage in order to control the high rotor currents. This means that the converter reaches fast its limits and as a consequence it looses the control of the generator during the grid fault. As the grid voltage drops in the fault moment, the GSC is not able to transfer the power from the RSC further to the grid and, therefore, the additional energy goes into charging the dc-bus capacitor and thus dc-bus voltage rises rapidly. It is therefore necessary to protect the converter against overcurrents, the rotor of the generator against overvoltages and the dc-link against overvoltages. The protection system monitors usually different signals, such as the rotor current, the dc-link voltage, and when at least one of the monitored signals exceeds its respective relay settings, the protection is activated. A simple protection method of the DFIG under grid faults is to short circuit the rotor through a device called crowbar. The crowbar protection is an external rotor impedance, coupled via the slip rings to the generator rotor instead of the converter, as illustrated in. The value of the crowbar resistance is dependent on the generator data, and therefore in case of another generator, a new value of the external rotor resistance has to be chosen [3]. The function of the crowbar is to limit the rotor current. When the crowbar is triggered, the RSC is disabled and bypassed, and therefore the independent controllability of active and reactive power gets unfortunately lost. Generator magnetization is in this case done over the stator, instead of being done over the rotor circuit by the RSC. Since the GSC is not directly connected to the generator windings, where the high transient currents occur, this converter is not blocked for protection.The crowbar protection is an integral part of the DFIG model in PowerFactory, while its control is modelled using the dynamic simulation language of the considered power system toolbox. The crowbar protection can be removed after a predefined time or according to additional criteria, such as the magnitude of the grid voltage. When the crowbar is removed, the RSC is enabled again to control independently the active and reactive power Fig. 6 illustrates the static curves for the torque and reactive power as function of speed for different crowbar resistances, applied for one 2MW DFIG.

Sudden change of load in IG and supply

Current wave form

Current wave form



1.13Fig

1.14 Behaviour immediately after the fault

In the fault instant, the voltage at the DFIG generator terminal drops and it leads to a corresponding decrease of the stator and rotor flux in the generator. This result in a reduction in the electromagnetic torque and active power—see. As the stator flux decreases, the magnetization that has been stored in the magnetic fields has to be released. The generator starts thus its demagnetization over the stator, which is illustrated in by the reactive power peak in the moment of the fault. As the electromagnetic torque of the generator drops according to the voltage drop too, the torsion spring in the drive train gets untwisted and therefore the mechanical torque drops too. However the drop of the mechanical torque is slower than of the electromagnetic torque, and therefore the generator starts to accelerate. The dynamic relation between the electrical torque, mechanical torque and the generator speed is reflected in. The over-speeding of the generator during the fault is counteracted by the pitch control system, sketched in and illustrated in In the fault moment, as the stator voltage decreases significantly, high current transients appear in the stator and rotor windings. Note that the rotor current resembles the stator current. In order to compensate for the increasing rotor current, the RSC increases the rotor voltage reference, which implies a "rush" of power from the rotor terminals through the converter. On the other side, as the grid voltage has dropped immediately after the fault, the GSC is not able to transfer the whole power from the rotor through the converter further to the grid. The GSC's control of the dc-voltage reaches thus quickly its limitation. As a result, the additional energy goes into charging the dc-bus capacitor and the dc-voltage rises rapidly .Exceeding the limit of the rotor current or of the dc-voltage activates the protection system. This short circuits the generator rotor by triggering the crowbar. The RSC is blocked and therefore its control of the rotor currents is disabled. In the moment the crowbar is triggered, the dc-bus capacitor starts discharging; the GSC begins to control the dc-link voltage back to its reference. Note that, as long as the crowbar is triggered, the generator behaves as a conventional SCIG, namely the converter rotor voltage output is zero.

1.15 Behaviour after fault clearance

Immediately after the fault is cleared, the stator voltage is restored, the electromagnetic torque and active power start to increase—. As the grid voltage and the flux increases, the demagnetized stator and rotor oppose this change in flux leading thus to an increase in the rotor and stator currents. Note that when the fault is cleared, the voltage does not recover completely immediately. Just after fault clearance, it reaches a voltage level lower than its nominal value, while it reaches completely its nominal voltage level after the removing of the crowbar. The reason for that is that just after fault clearance the generator continues to behave as SCIG, and therefore it starts to absorb reactive power for its magnetizationThe RSC is disabled until the crowbar is removed, and therefore it is not able to provide the reactive power necessary for the magnetization of the generator. The generator absorbs thus reactive power from the grid and this action delays the recovering process of the grid voltage.

When the grid voltage recovers over a certain value, the crowbar is removed. From this moment, the voltage recovers completely, the generator currents and voltages start to converge to their pre-fault values and the RSC starts actively to control the active and reactive power.

The detailed simulations illustrated and provide a quick overview and a better understanding of the functionality of the DFIG wind turbine control and protection during grid fault.

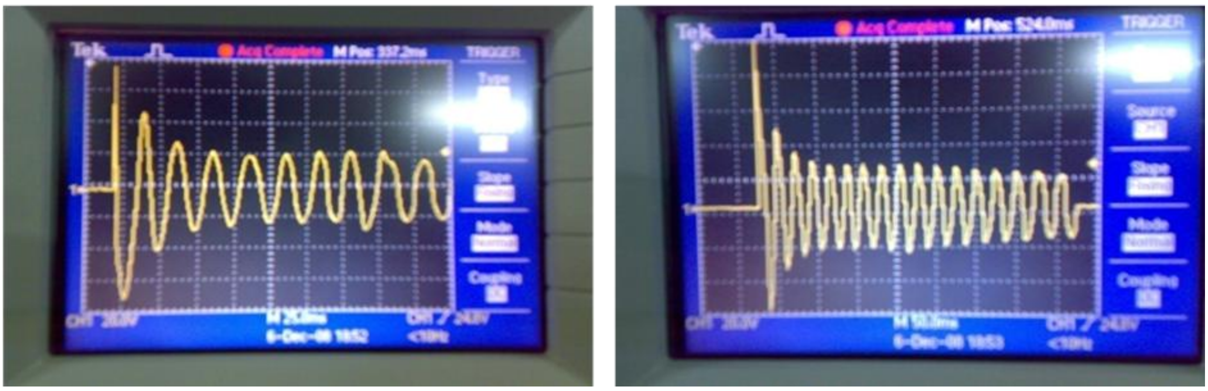
Transient behaviors

The paper assesses the fault ride-through capability of DFIG wind turbines. It illustrates the interaction between DFIG variable-speed wind turbines and the power system itself during grid faults. Issues on modelling and control of a DFIG wind turbine with focus on the converter protection under grid fault operation are discussed.

The dynamic model of variable-speed DFIG wind turbines with the fault ride-through control and protection is implemented in the power system analysis. From the transient stability point of view, the drive train of the wind turbine has to be represented by a two-mass model in order to be able to simulate the torsional oscillations excited in the drive train system during grid faults. A damping controller has to be implemented and tuned to damp actively these oscillations, which otherwise might lead to self-excitation and high mechanical stress of the drive train system. The converter control and protection is essential for the fault ride-through capability of the DFIG wind turbine. The protection system of the converter (i.e., crowbar resistance) is triggered when high transient currents and voltages occur in the generator and converter, otherwise the power converter device would be damaged during grid faults. When the crowbar is triggered, DFIG behaves as a conventional SCIG, and therefore its controllability is temporarily lost. The crowbar resistance, which value is strictly dependent on the generator data sheet, has influence on the rotor current and on the reactive power demands of the generator during grid faults.

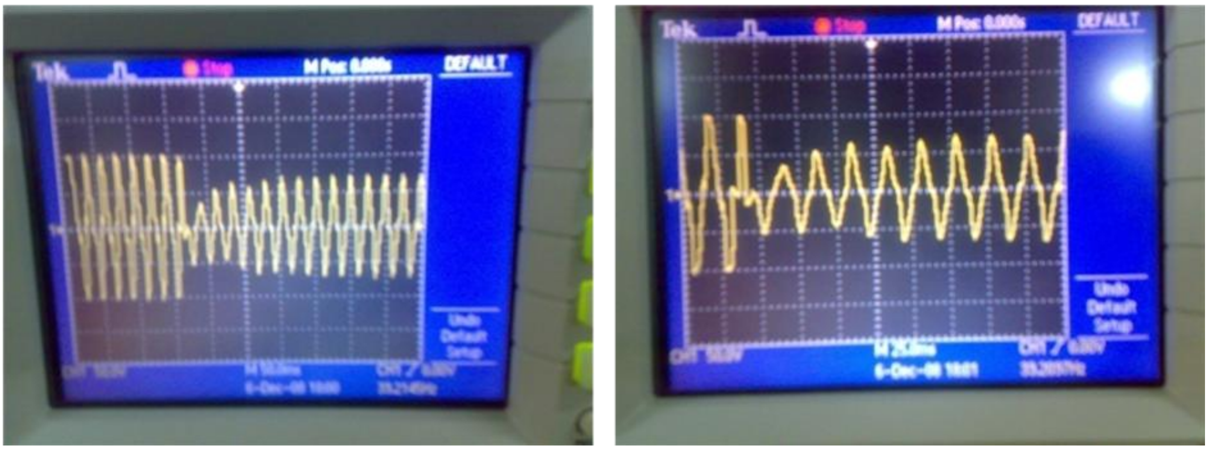
The implementation of the wind turbine control, converter control and protection is modelled on a generic level, without focusing on a particular manufacturer. A generic simplified model for the transmission power system, similar to that developed by the Danish Transmission System Operator Energinet.dk, is used in the investigations. The simulation results provide insight and understanding on the most significant phenomena concerning the behaviour of DFIG wind turbines during grid fault

current due to sudden change in load in IG and supply



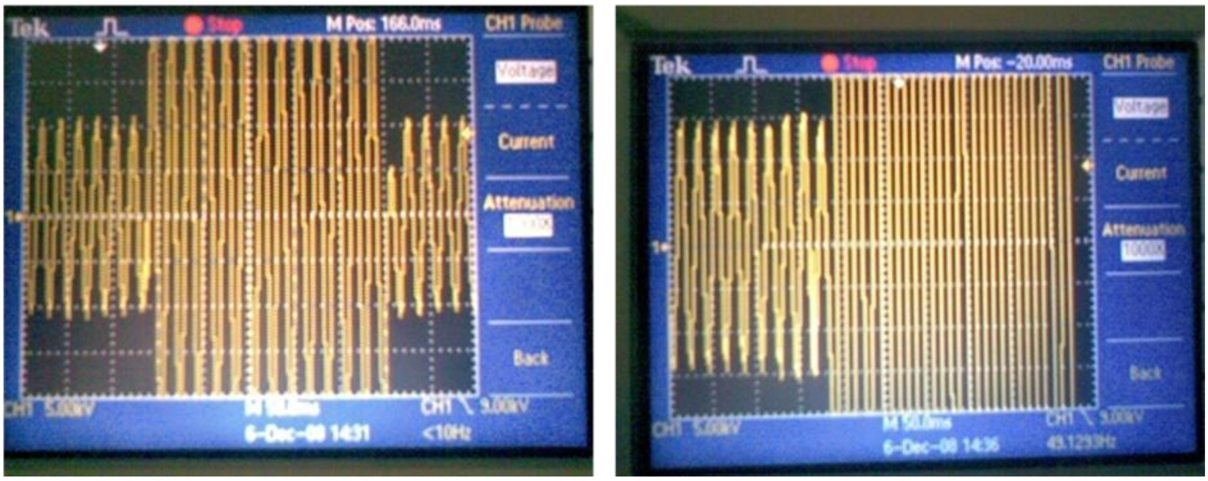
1.16Fig Another currentwave due to sudden change 3phase load box or grid.This is the current due to IG and supply power both.

current due to unbalance loading in IG and supply



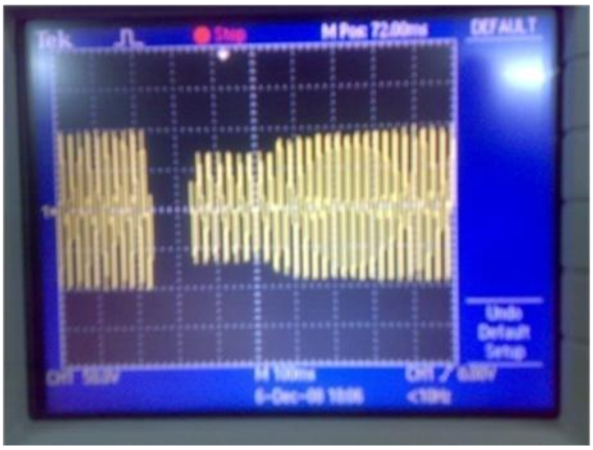
1.17Fig Unbalance load given to the load box,this is switching unbalance load current.

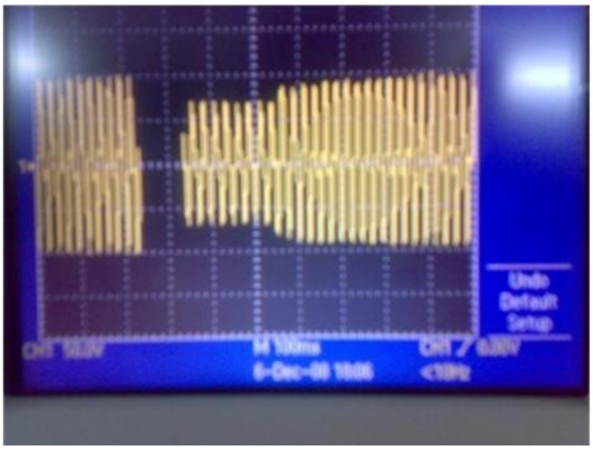
Voltage wave due to sudden change of load in IG and supply



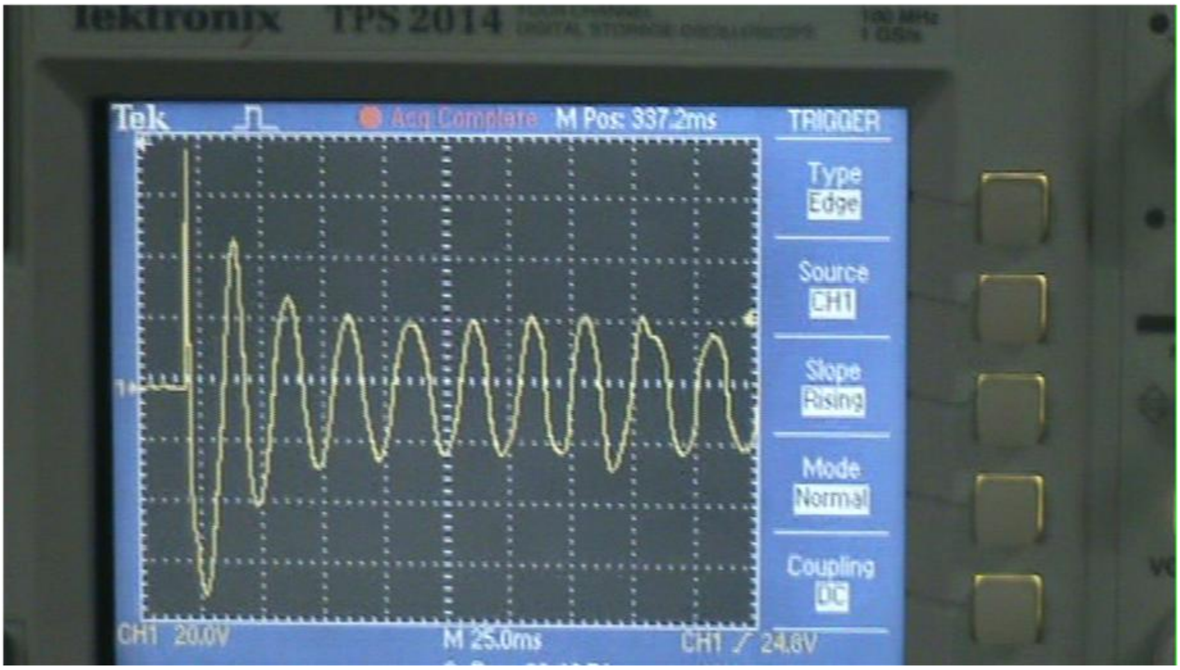
1.18Fig Phase voltagewave due to sudden change of load,it is measure for a short time on standard resister and storage oscilloscope.

voltage due to unbalance of loading in IG and supply



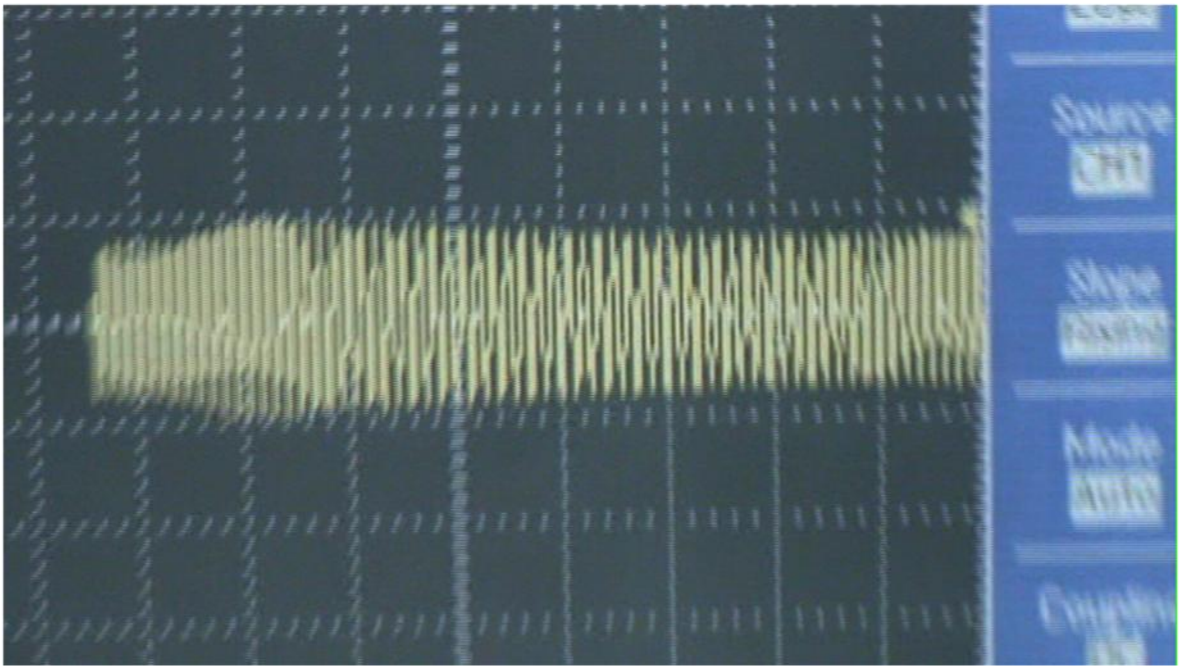


Current due to sudden change of load in IG



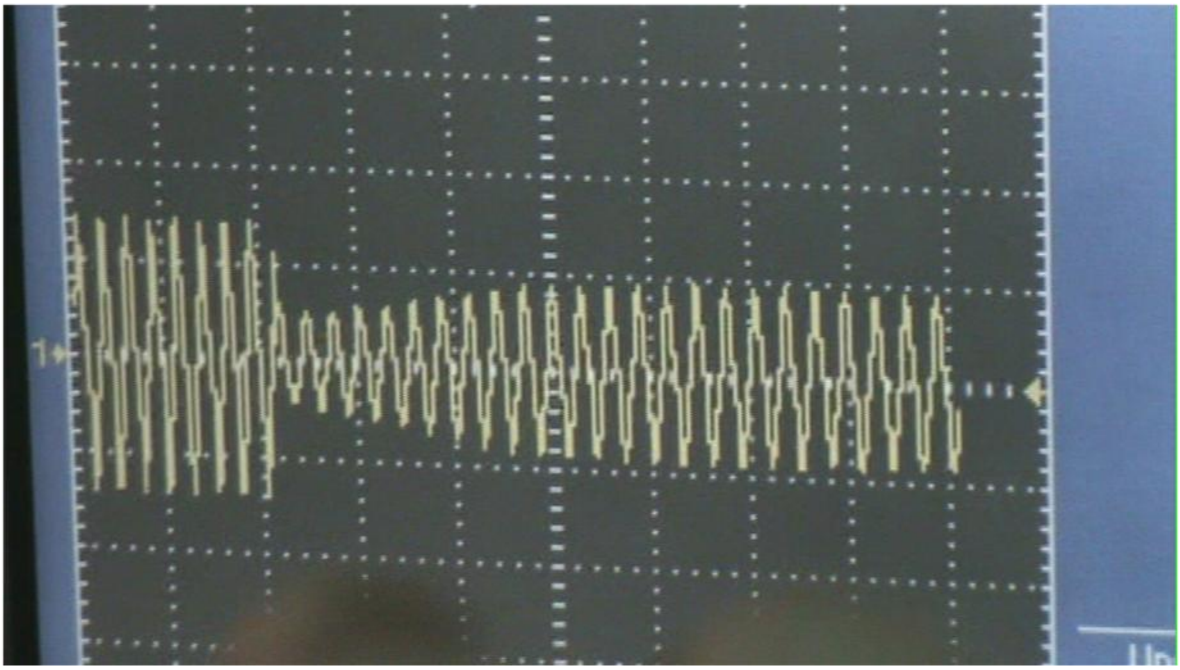
1.19Fig.

Current in sudden change of load in IG

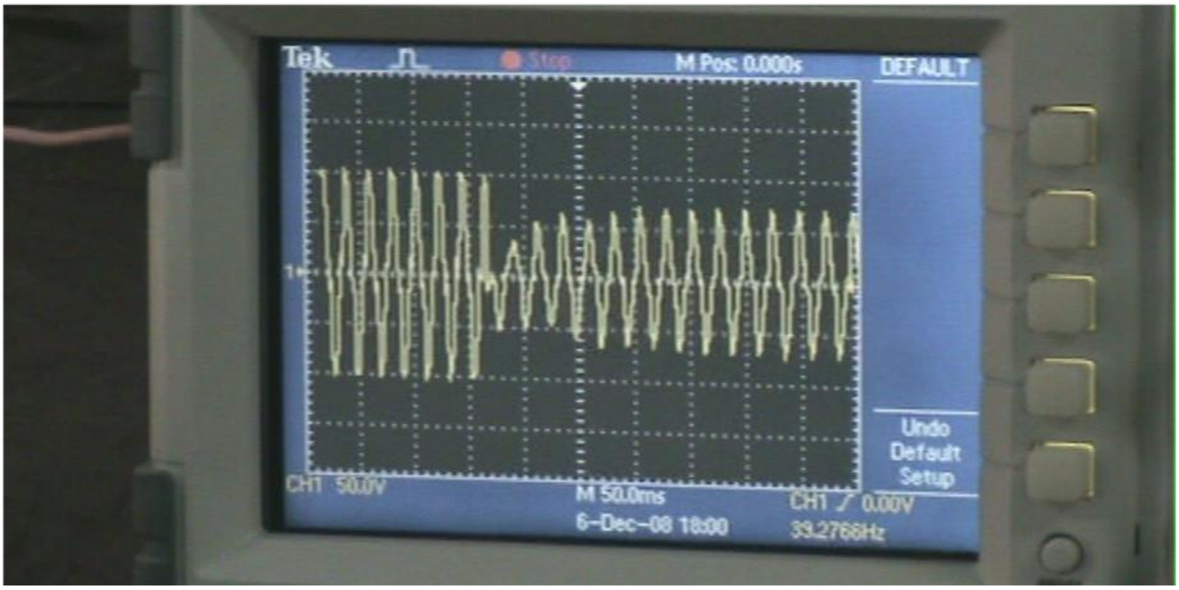


1.20Fig.

Voltage due to unbalance loading in IG

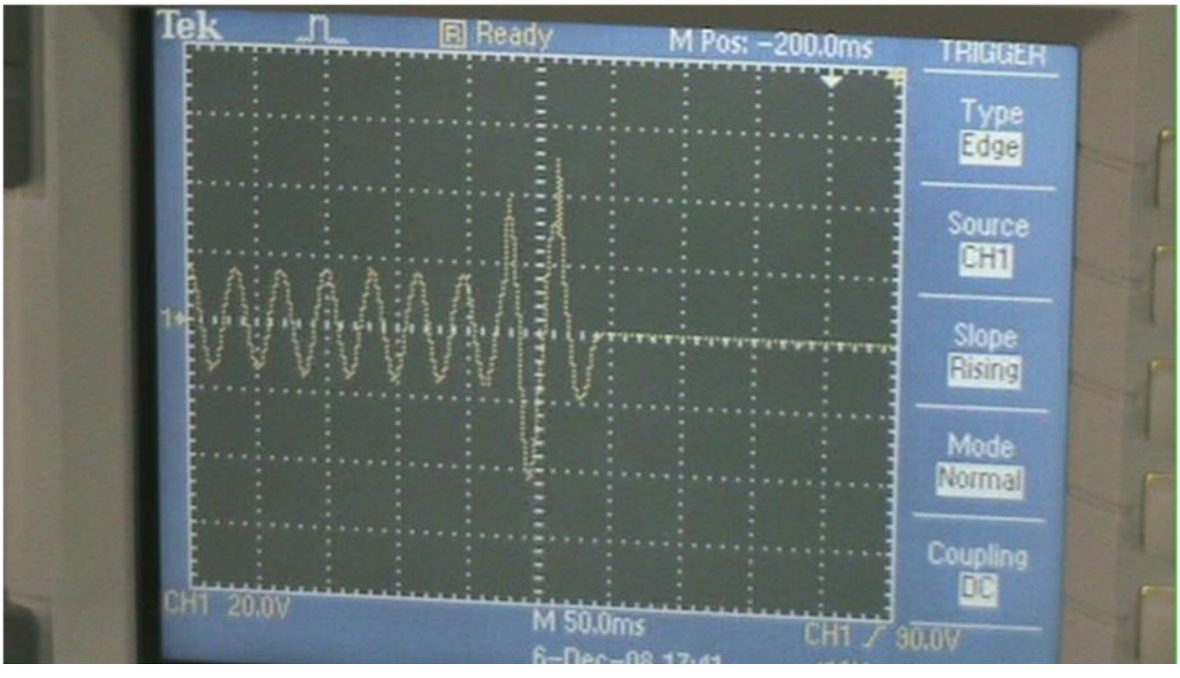


Voltage due to unbalance loading in IG

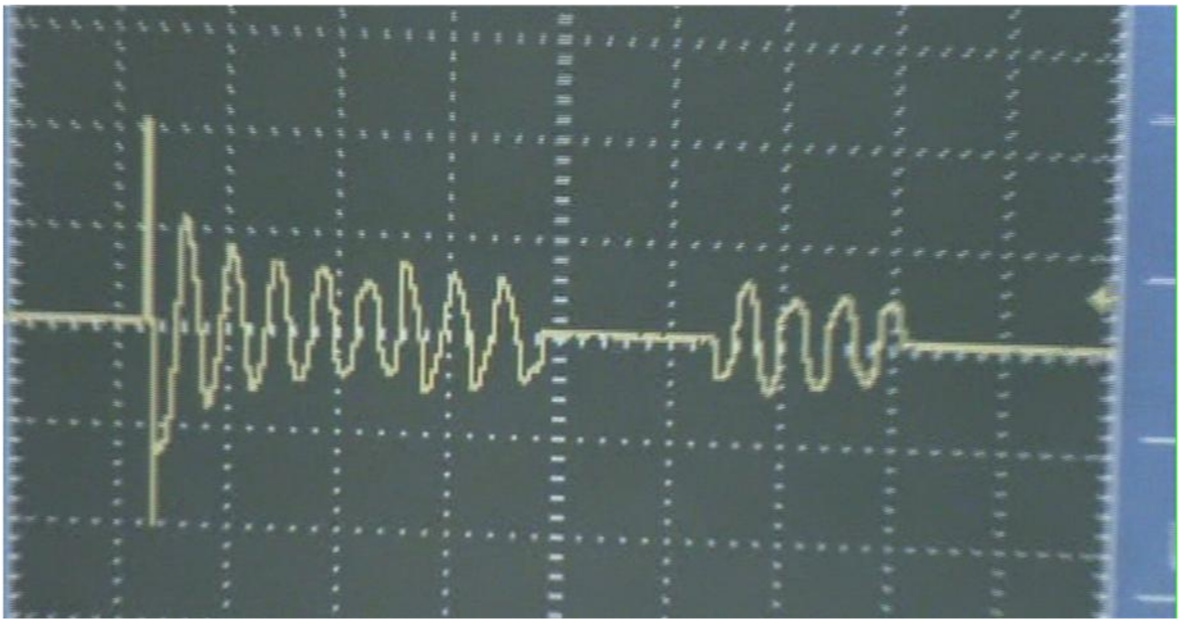


1.21Fig.

Current due to unbalancing of load in IG

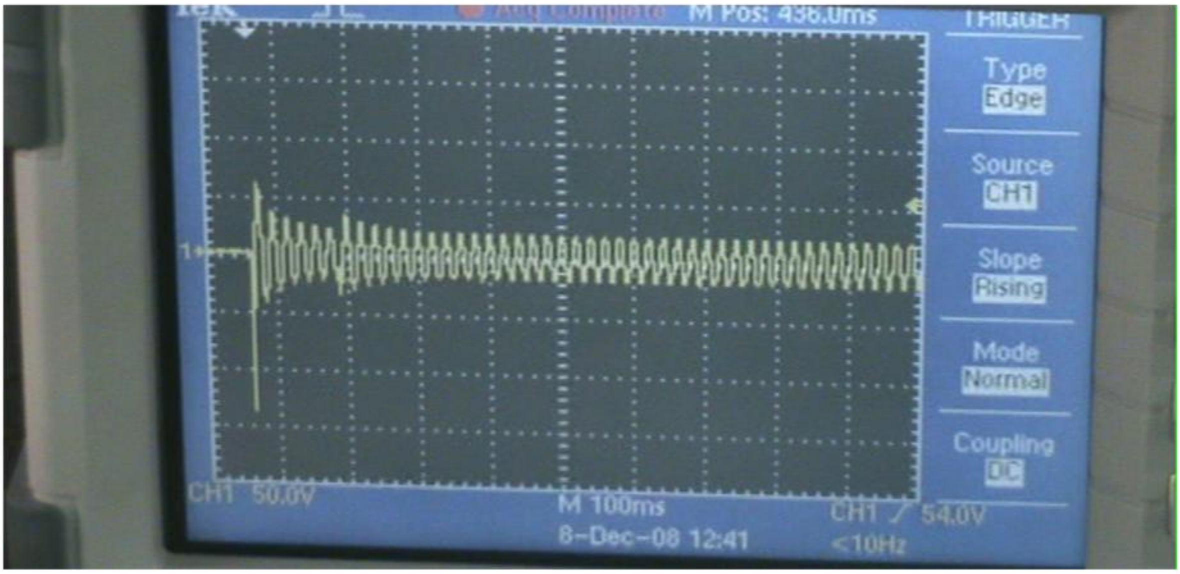


current wave due to L-L fault in IG



1.22Fig Making two phase short circuit for a short time ,this is the graph of the current.

Current,due to L-L fault of IG



1.23Fig This phase to phase fault of current due induction generator only.supply is disconnected from the grid.

INDUCTION MACHINE

Introduction

Dynamic d-q model

Induction machine control

DC drive analogy

Principle of vector control

Voltage model for signal estimation

2.1INTRODUCTION

Variable speed ac drives have been used in the past to perform relatively undemanding roles in application which preclude the use of dc motors, either because of the working environment or commutator limits. Because of the high cost of efficient, fast switching frequency static inverter, the lower cost of ac motors has also been a decisive economic factor in multi motor systems. However as a result of the progress in the field of power electronics, the continuing trend is towards cheaper and more effective power converters, and a single motor ac drives complete favorably on a purely economic basis with a dc drives.

Among the various ac drive systems, those which contain the cage induction motor have a particular cost advantage. The cage motor is simple and rugged and is one of the cheapest machines available at all power ratings. Owing to their excellent control capabilities, the variable speed drives incorporating ac motors and employing modern static converters and torque control can well complete with high performance four quadrant dc drives.

The Induction motors (IM) for many years have been regarded as the workhorse in industry. Recently, the induction motors were evolved from being a constant speed motors to a variable speed. In addition, the most famous method for controlling induction motor is by varying the stator voltage or frequency. To use this method, the ratio of the motor voltage and frequency should be approximately constant. With the invention of Field Orientated Control, the complex induction motor can be modeled as a DC motor by performing simple transformations. In a similar manner to a dc machine in induction motor the armature winding is also on the rotor, while the field is generated by currents in the stator winding. However the rotor current is not directly derived from an external source but results from the emf induced in the winding as a result of the relative motion of the rotor conductors with respect to the stator field. In other words, the stator current is the source of both the magnetic field and armature current. In the most commonly used, squirrel cage motor, only the stator current can directly be controlled, since the rotor winding is not accessible. Optimal torque production condition are not inherent due to the absence of a fixed physical disposition between the stator and rotor fields, and the torque equation is non linear. In effect, independent and efficient control of the field and torque is not as simple and straightforward as in the dc motor.

The concept of the steady state torque control of an induction motor is extended to transient states of operation in the high performance, vector control ac drive system based on the field operation principle (FOP). The FOP defines condition for decoupling the field control from the torque control. A field oriented induction motor emulates a separately exited dc motor in two aspects:

- Both the magnetic field and torque developed in the motor can be controlled independently.
- Optimal condition for the torque production, resulting in the maximum torque per unit ampere, occurs in the motor both in steady state and in transient condition of operation.

2.2 DYNAMIC d-q MODEL

R.H. Park in 1920's proposed a model for synchronous machine with respect to stationary ref frame. H.C. Stanley in 1930's proposed a model for induction machine with respect to stationary reference frame. Later G. Bryon's proposed a transformation of both stator and rotor variables to a synchronously rotating reference frame that moves with the rotating magnetic field. Lastly Krause and Thomas proposed a model for induction machine with respect to stationary reference frame.

2.2.1 Axes transformation

Consider a three phase induction machine with stationary stator winding axes as-bs-cs with voltages v_{as} , v_{bs}, v_{cs} and the stationary ref. frame are d^s - q^s with voltages v_d^s, v_q^s . Let, v_{as} makes an angle θ with v_q^s . [12]Assume that the d^s - q^saxes are oriented at an angle θ. The voltages $v_d^s - v_q^s$ can be resolved into as-bs-cs components.

$$\begin{bmatrix} v_{as} \\ v_{bs} \\ v_{cs} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta - 120°) & \sin(\theta - 120°) & 1 \\ \cos(\theta + 120°) & \sin(\theta + 120°) & 1 \end{bmatrix} \begin{bmatrix} v_{qs}^s \\ v_{ds}^s \\ v_{os}^s \end{bmatrix} \tag{2.1}$$

The corresponding inverse relation is

$$\begin{bmatrix} v_{qs}^s \\ v_{ds}^s \\ v_{0s}^s \end{bmatrix} = \begin{bmatrix} \cos\theta & \cos(\theta-120^\circ) & \cos(\theta+120^\circ) \\ \sin\theta & \sin(\theta-120^\circ) & \sin(\theta+120^\circ) \\ 0.5 & 0.5 & 0.5 \end{bmatrix} \begin{bmatrix} v_{as} \\ v_{bs} \\ v_{cs} \end{bmatrix} \tag{2.2}$$

The voltages on the d^s - q^s can be converted into d^e - q^e frame:

$$v_{qs} = v_{qs}^s \cos\theta_e - v_{ds}^s \sin\theta_e \tag{2.3}$$

$$v_{ds} = v_{qs}^s \sin\theta_e - v_{ds}^s \cos\theta_e \tag{2.4}$$

Resolving the rotating frame parameter into stationary frame:

$$v_{qs}^s = v_{qs} \cos\theta_e + v_{ds} \sin\theta_e \tag{2.5}$$

$$v_{ds}^s = - v_{qs} \sin\theta_e + v_{ds} \cos\theta_e \tag{2.6}$$

Let, $v_{as} = v_m \cos(\omega_e t + \emptyset)$ (2.7)

$$v_{bs} = v_m \cos\left(\omega_e t - \frac{2\pi}{3} + \emptyset\right) \tag{2.8}$$

$$v_{cs} = v_m \cos\left(\omega_e t + \frac{2\pi}{3} + \emptyset\right) \tag{2.9}$$

From equation:

$$v_{qs}^s = v_m \cos(\omega_e t + \emptyset) \tag{2.10}$$

$$v_{ds}^s = - v_m \sin(\omega_e t + \emptyset) \tag{2.11}$$

Form equation:

$$v_{qs} = v_m \cos\emptyset \tag{2.12}$$

$$v_{ds} = -v_m \sin \emptyset \qquad (2.13)$$

This shows that the sinusoidal variables in a stationary frame appear as DC quantity.

$$|\bar{V}| = V_m \qquad (2.14)$$

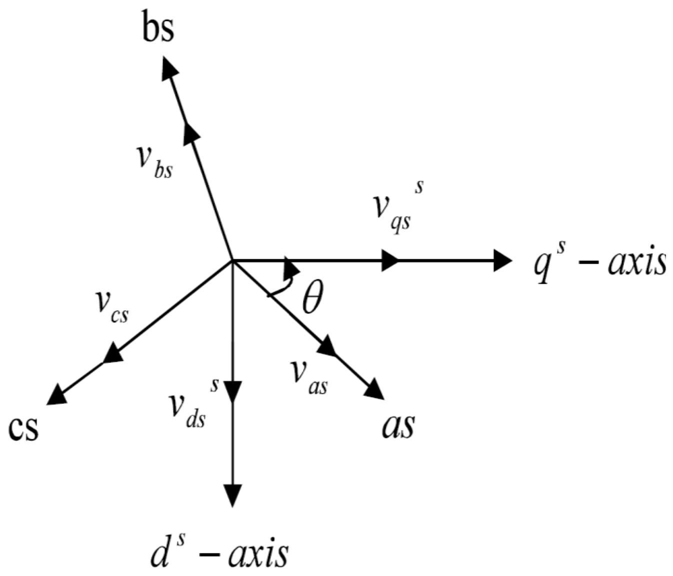


Fig. 2.1 Stationary frame a-b-c to d^s - q^s axes transformation.

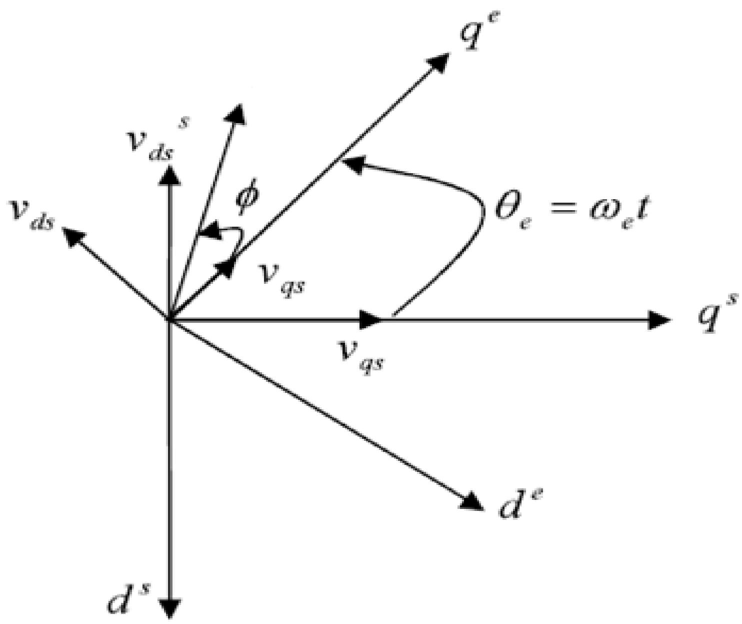


Fig. 2.2 Stationary frame d^s - q^s to synchronous rotating frame d^e-q^e

2.2.2 Synchronously rotating reference frame-Dynamic model (Kron's equation)

The stator circuit equations are:

$$v_{qs}^{s} = R_s i_{qs}^{s} + \frac{d}{dt}\psi_{qs}^{s} \qquad (2.15)$$

$$v_{ds}^{s} = R_s i_{ds}^{s} + \frac{d}{dt}\psi_{ds}^{s} \qquad (2.16)$$

Where, ψ_{qs}^{s} = q axis flux linkage

ψ_{ds}^{s} = d axis flux linkage

$$v_{qs} = R_s i_{qs} + \frac{d}{dt}\psi_{qs}^{s} + \omega_e \psi_{ds} \qquad (2.17)$$

$$v_{ds} = R_s i_{ds} + \frac{d}{dt}\psi_{ds}^{s} - \omega_e \psi_{ds} \qquad (2.18)$$

If the rotor is not rotating, the rotor equations will be written as:

$$v_{qr} = R_r i_{qr} + \frac{d}{dt}\psi_{qr}^{s} + \omega_e \psi_{dr} \qquad (2.19)$$

$$v_{dr} = R_r i_{dr} + \frac{d}{dt}\psi_{dr}^{s} + \omega_e \psi_{qr} \qquad (2.20)$$

If rotor rotates, then the equation will be:

$$v_{qr} = R_r i_{qr} + \frac{d}{dt}\psi_{qr}^{s} + (\omega_e - \omega_r)\psi_{dr} \qquad (2.21)$$

$$v_{dr} = R_r i_{dr} + \frac{d}{dt}\psi_{dr}^{s} - (\omega_e - \omega_r)\psi_{qr} \qquad (2.22)$$

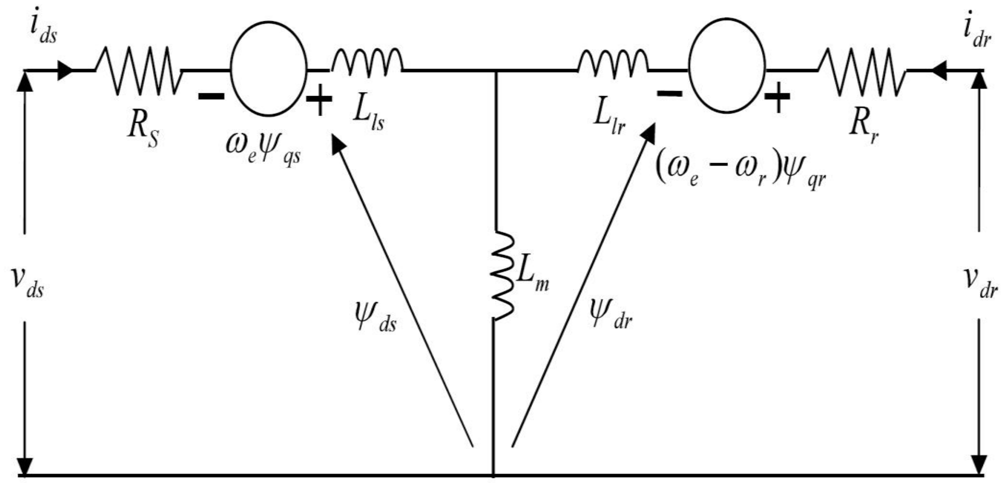


Fig. 2.3 Dynamic d^e axis circuit

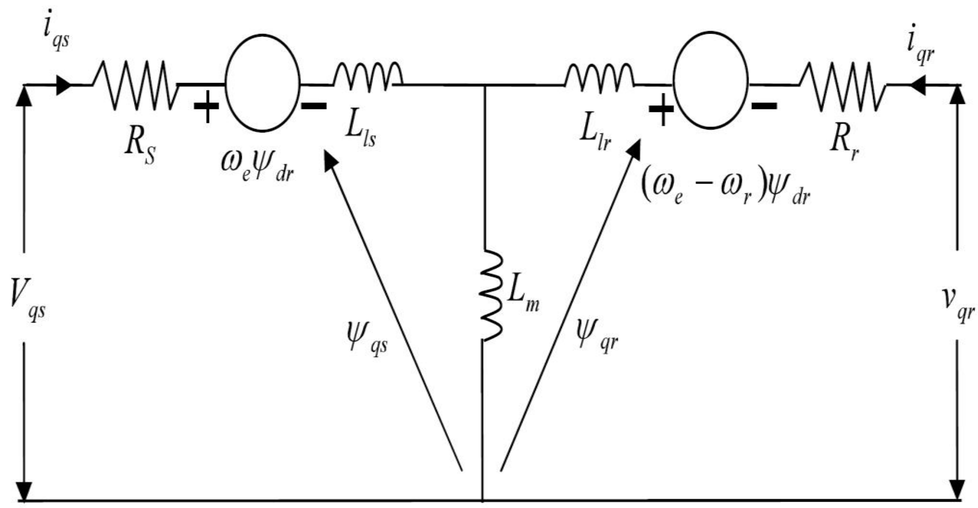


Fig. 2.4 Dynamic q^e axis circuit

The flux linkage expressions in terms of the circuit currents are:

$$\psi_{qs} = L_{ls}\, i_{qs} + L_m\,(i_{qs}+i_{qr}) \tag{2.23}$$

$$\psi_{qr} = L_{lr}\, i_{qr} + L_m\,(i_{qs}+i_{qr}) \tag{2.24}$$

$$\psi_{ds} = L_{ls}\, i_{ds} + L_m\,(i_{ds}+i_{dr}) \tag{2.25}$$

$$\psi_{dr} = L_{lr}\, i_{dr} + L_m\,(i_{ds}+i_{dr}) \tag{2.26}$$

$$\psi_{qm} = L_m\,(i_{qs}+i_{qr}) \tag{2.27}$$

$$\psi_{dm} = L_m\,(i_{ds}+i_{dr}) \tag{2.28}$$

$$\begin{bmatrix} v_{qs} \\ v_{ds} \\ v_{qr} \\ v_{dr} \end{bmatrix} = \begin{bmatrix} R_s + SL_s & \omega_e L_s & SL_m & \omega_e L_m \\ -\omega_e L_s & R_s + SL_s & -\omega_e L_m & SL_m \\ SL_s & (\omega_e - \omega_r) L_m & R_r + SL_r & (\omega_e - \omega_r) L_r \\ -(\omega_e - \omega_r) L_m & SL_m & -(\omega_e - \omega_r) L_r & R_r + SL_r \end{bmatrix} \begin{bmatrix} i_{qs} \\ i_{ds} \\ i_{qr} \\ i_{dr} \end{bmatrix}$$

…………… (2.29)

The torque is given by:

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)\ \psi_m \times I_r \tag{2.30}$$

2.3 INDUCTION MACHINE CONTROL:

Squirrel cage induction machines are simple and rugged and are considered to be the workhorses of industry. At present induction motor drives dominate the world market. However, the control structure of an induction motor is complicated since the stator field is revolving, and further complications arises due to the fact that the rotor currents or rotor flux of a squirrel cage induction motor can not be directly monitored The mechanism of torque production in an ac machine and in a dc machine is similar. Unfortunately this similarity was not emphasized before the 1970s, and this is one of the reasons why the technique of vector control did not emerge earlier. The formulae given in many well known textbook of the machine theory have also implied that, for the monitoring of the instantaneous electromagnetic torque of an induction machine, it is also necessary to monitor the rotor currents and the rotor position. Even in the 1980s some publications seemed to strengthen this false conception, which only arose because the complicated formulae derived for the expression of the instantaneous electromagnetic torque have not been simplified. However by using fundamental physical laws or space vector theory, it is easy to show that, similar to the expression of the electromagnetic torque of a separately exited dc machine, the instantaneous electromagnetic torque of an induction motor can be expressed as the product of a flux producing current and a torque producing current, if a special flux oriented reference is used.

2.3.1 Scalar control

Scalar control, as the name indicates, is due to magnitude variation of the control variables only, and disregarding the coupling effect in the machine. For example, the voltage of the machine can be controlled to control the flux, and the frequency and slip can be controlled to control the torque. However, flux and torque are also functions of frequency and voltage, respectively. Scalar control in contrast to the vector control or field oriented control, where both the magnitude and phase is controlled. Scalar controlled drives give some what inferior performance, but they are easily implemented. Scalar controlled drives have been widely used in industry. How ever their importance has diminished recently because of the superior performance of vector controlled drives, which is demanded in many applications.

2.3.2 Vector control or field oriented control

Scalar control is somewhat simple to implement, but the inherent coupling effect i.e. both torque and flux are functions of voltage or current and frequency gives the sluggish response and the system is easily prone to instability because of high order system harmonics. For example, if the torque is increased by incrementing the slip or slip the flux tends to decrease. The flux variation is sluggish. The flux variation then compensated by the sluggish flux control loop feeding additional voltage. This temporary dipping of flux reduces the torque sensitivity with slip and lengthens the system response time

These foregoing problems can be solved by vector control or field oriented control. The invention of vector control in the beginning of 1970s, and the demonstration that an induction motor can be controlled like a separately excited dc motor, brought a renaissance in the high performance control of ac drives. Because of dc machine like performance, vector control is known as decoupling, orthogonal, or trans vector control. Vector control is applicable to both induction and synchronous motor drives. Vector control and the corresponding feedback signal processing, particularly for modern sensor less vector control, are complex and the use of powerful microcomputer or DSP is mandatory. It appears that eventually, vector control will oust scalar control, and will be accepted as the industry standard control for ac drives.

2.4 DC DRIVE ANALOGY

Ideally, a vector controlled induction motor drive operates like a separately excited dc motor drive in fig 1.1. In a dc machine, neglecting the armature reaction effect and field saturation, the developed torque is given by

$$T_e = K_t \psi_f \psi_a = K_t' I_f I_a \qquad (2.4.1)$$

Where, I_a = armature current

And I_f = field current

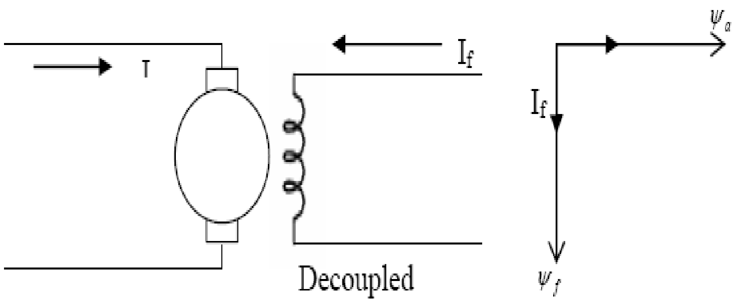


Fig. 2.5 separately exited DC motor

This construction of dc machine is such that the field flux ψ_f produced by the current I_f is perpendicular to the armature flux ψ_a ,which is produced by the armature current. These space vectors, which are stationary in space, are orthogonal and decoupled in nature. This means that when torque is controlled by controlling the current I_a the flux ψ_f is not affected and we get the fast transient response and high torque ampere ratio. Because of decoupling, when the field current I_f is controlled, it affects the field flux ψ_f only, but not the ψ_a flux. Because of the inherent coupling problem, an induction motor can not generally give such fast response.

DC machine like performance can also be extended to an induction motor if the machine is considered in a synchronously rotating reference frame ($d^e - q^e$), where the sinusoidal variables appears as dc quantity in steady.

In fig 1.2, the induction motor with the inverter and vector control in the front end is shown with two control current inputs i_{ds}^* and i_{qs}^*.These currents are the direct axis component and quadrature axis component of the stator current, respectively, in a synchronously rotating reference frame.

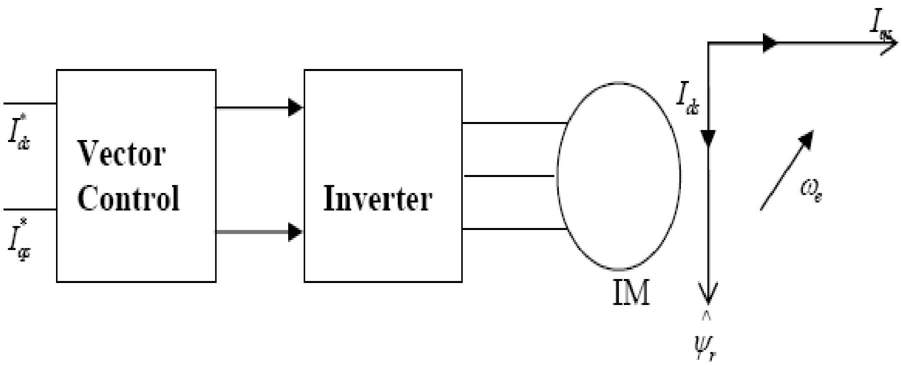


Fig. 2.6 vector controlled induction motor

With vector control, i_{ds} is analogous to field current I_f and i_{qs} is analogous to armature Current I_a of a dc machine. Therefore, the torque can be expressed as

$$T_e = K_t \, \hat{\psi}_r I_{qs} = K_t' I_{qs} I_{ds} \qquad (2.4.2)$$

Where, $\bar{\psi}_r$= absolute peak value of the sinusoidal space vector. This dc machine like performance is only possible if i_{ds} is oriented in the direction of $\bar{\psi}_r$ and i_{qs} is established perpendicular to it, as shown by the space vector diagram of fig 2.2. This means that when i_{qs}^* is controlled; it affects the actual i_{qs} current only, but does not affect the flux $\bar{\psi}_r$. Similarly, when i_{ds}^* is controlled, it controls the flux only and does not affect the i_{ds} component of current. This vector or field orientation of current is essential under all operating condition in a vector control drive. When compared to dc machine space vectors, induction machine space vector rotate synchronously at frequency ω_e as indicated in fig 2.2.

2.5 PRINCIPAL OF VECTOR CONTROL

The fundamentals of vector control implementation can be explained with the help of fig. 2.7 where the machine model is represented in a synchronously rotating reference frame. The inverter is omitted from the figure, assuming that it has unity current gain, that is, it generates currents i_a, i_b, and i_c *as* dictated by the corresponding commands currents i_a^*, i_b^* and i_c^* from the controller. A machine model with internal conversions is shown on the right. The machine terminal phase currents i_a, i_b and i_c are converted to I_{ds}^s and I_{qs}^s component by $3\varphi/2\varphi$ transformation.

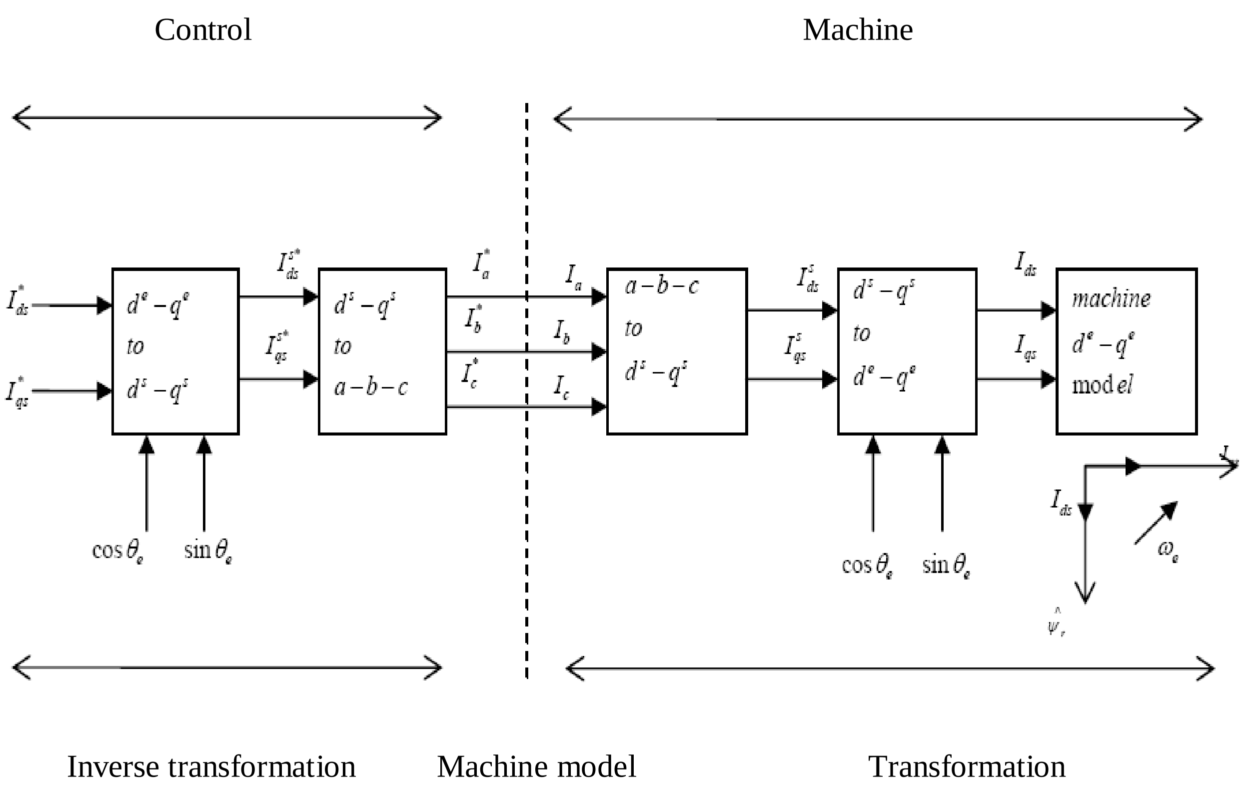
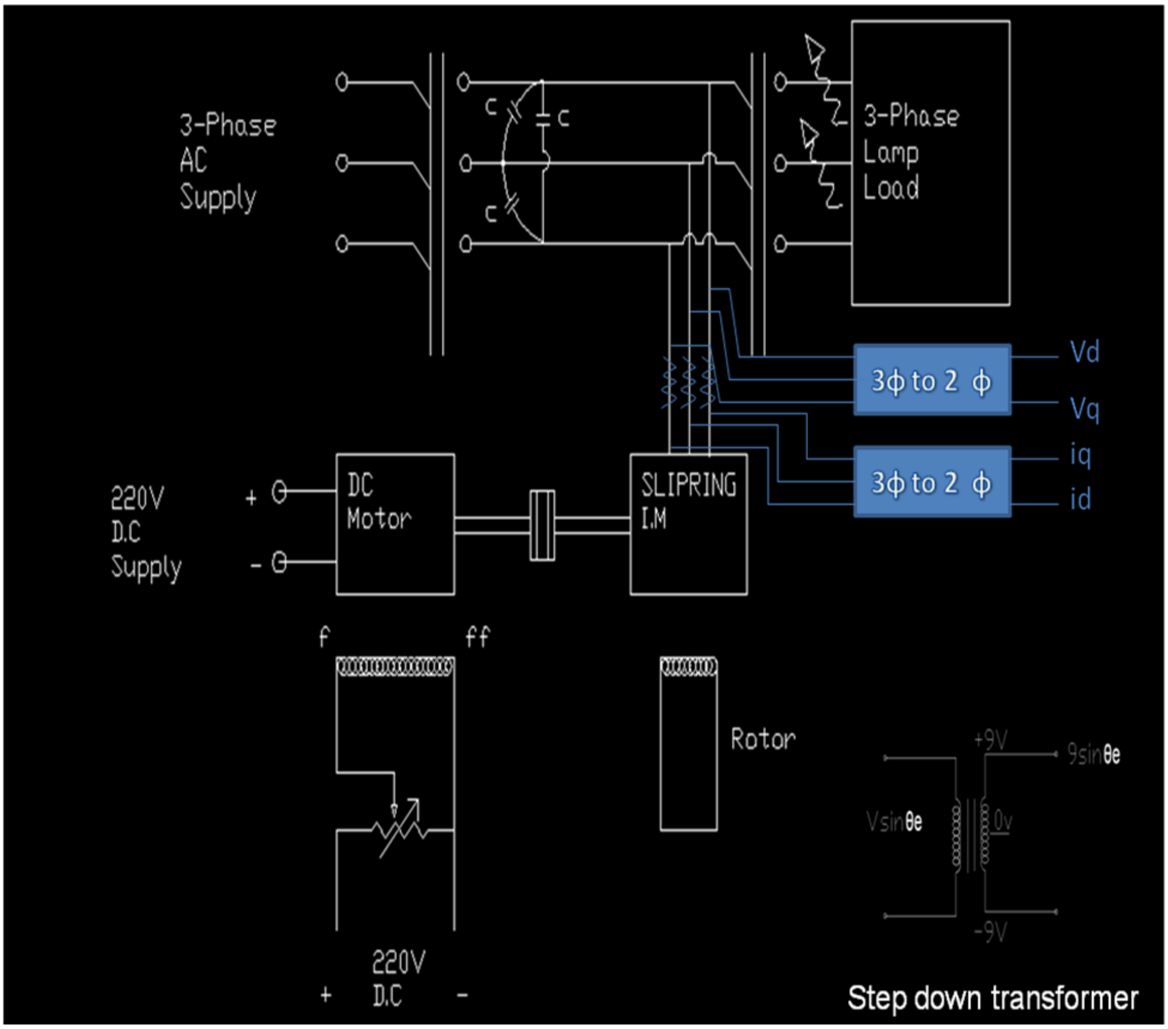


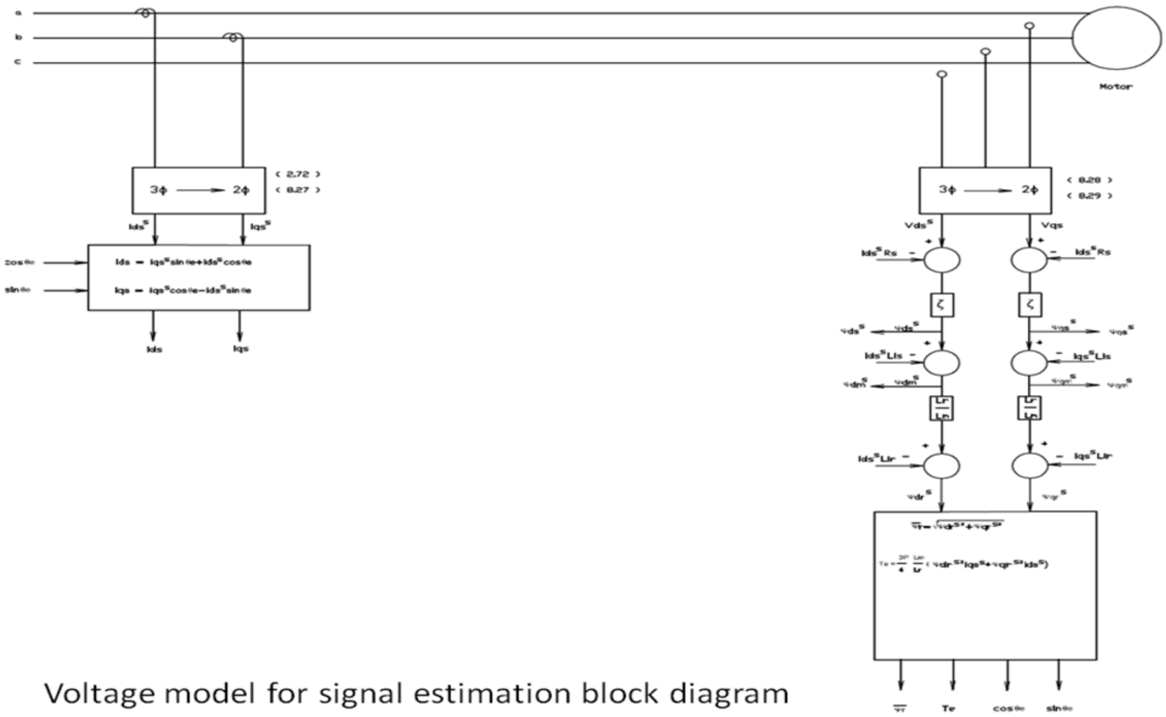
Fig. 2.7 vector control implementation principle with machine ($d^e\!-\!q^e$) model.

These are then converted to synchronously rotating frame by the unit vector components $\cos\theta_e$ and $\sin\theta_e$ before applying them to the $d^e\!-\!q^e$ machine model as shown in the fig 1.3. The controller makes two stage of inverse transformation, as shown, so that the control currents i_{ds}^* and i_{qs}^* corresponds to the machine current i_{ds} and i_{qs}, respectively. The transformation and inverse transformation including the inverter ideally do not incorporate any dynamics therefore, the response to i_{ds} and i_{qs} is instantaneous.

2.6Circuit diagram

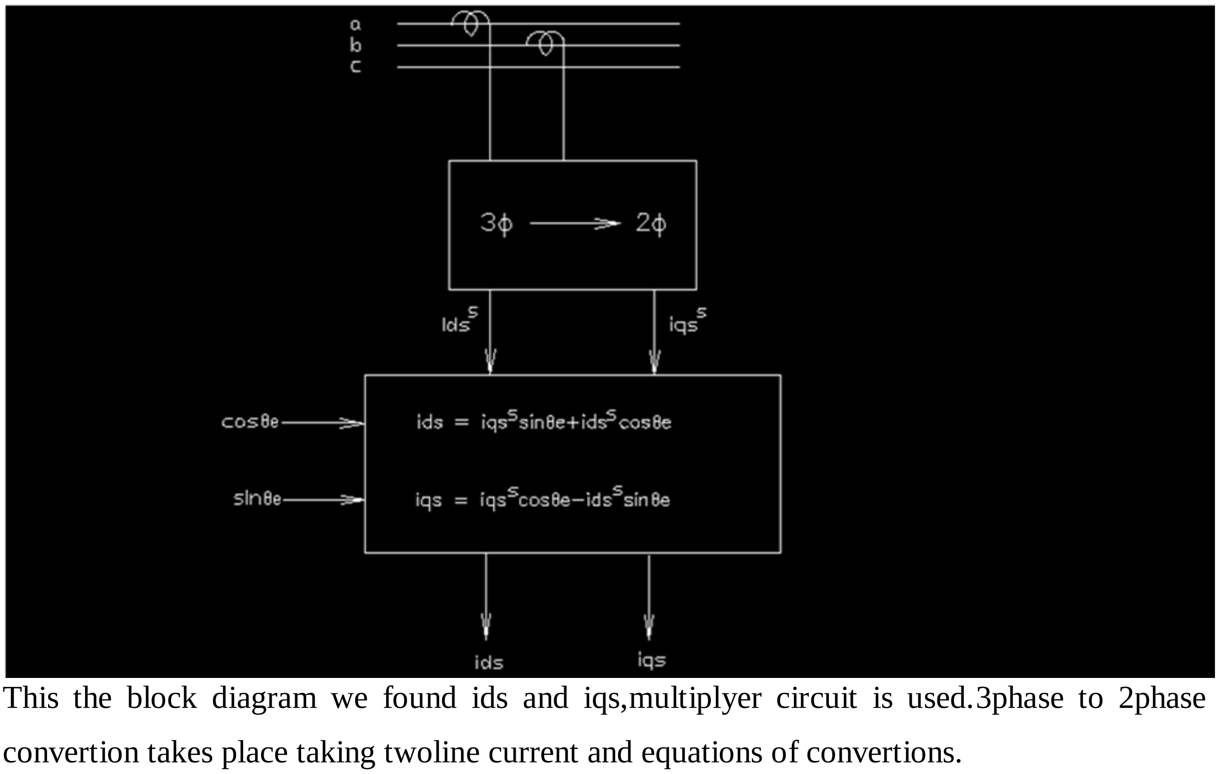


This is the circuit diagram of IG and supply,here 3phase to two phase convertion circuit added to the circuit.,stepdown transformer down the voltage up to9-0-9volt.



Voltage model for signal estimation block diagram

2.7Fig



This the block diagram we found ids and iqs,multiplyer circuit is used.3phase to 2phase convertion takes place taking twoline current and equations of convertions.

Terminal current from the stationary frame $d^s - q^s$

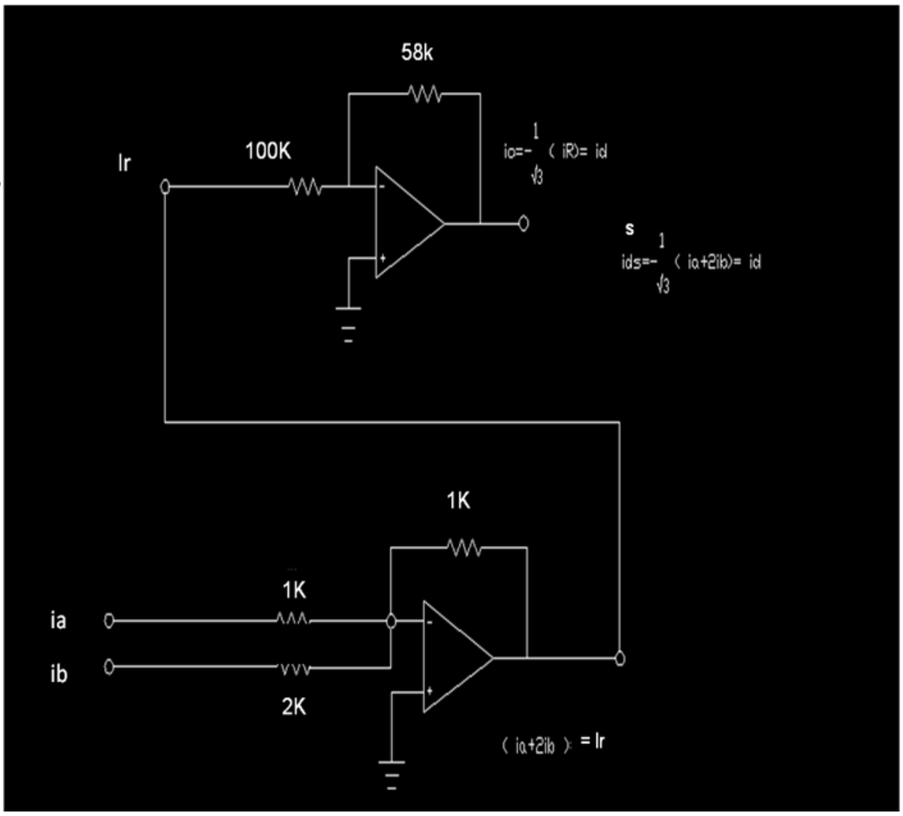
$$i_{qs}^{s} = \frac{2}{3} i_a - \frac{1}{3} i_b - \frac{1}{3} i_c = i_a$$

$$i_{ds}^{s} = -\frac{1}{\sqrt{3}} i_b + \frac{1}{\sqrt{3}} i_c$$

$$i_{ds}^{s} = -\frac{1}{\sqrt{3}} (i_a + 2 i_b)$$

$$i_c = -(i_a + i_b)$$ For isolated neutral load

$Vds = -\frac{1}{\sqrt{3}}(Va + 2Vb) = Vd$



$Vds = -\frac{1}{\sqrt{3}}(Va + 2Vb) = Vd$

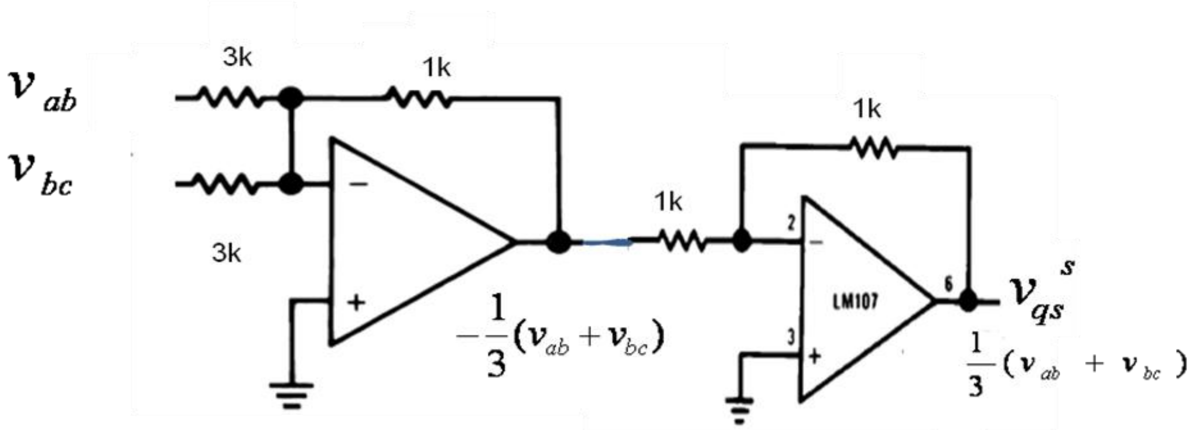
2.8 Here we got stationary ids.

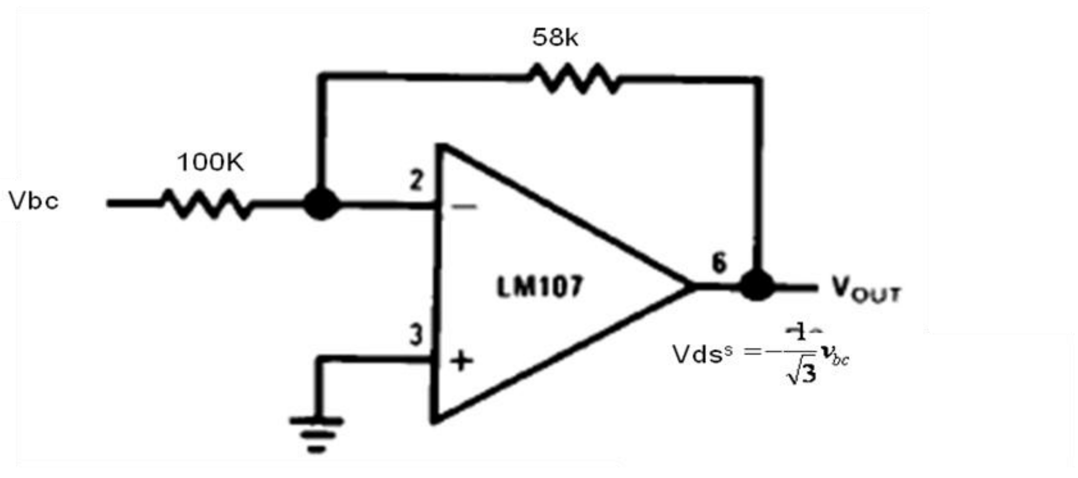
Terminal voltage from the stationary frame $d^s - q^s$

$$v_{qs}{}^{s} = \frac{2}{3}v_a - \frac{1}{3}v_b - \frac{1}{3}v_c = \frac{1}{3}(v_{ab} + v_{ac})$$

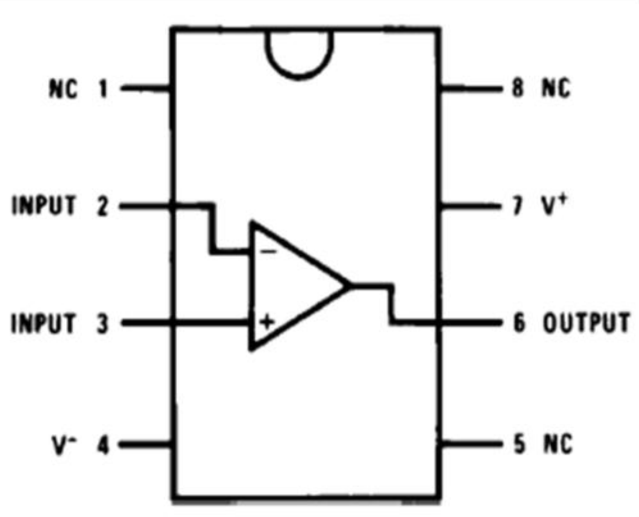
$$v_{ds}{}^{s} = -\frac{1}{\sqrt{3}}v_b + \frac{1}{\sqrt{3}}v_c = -\frac{1}{\sqrt{3}}v_{bc}$$

Find Vqs(stastic frame of reference)



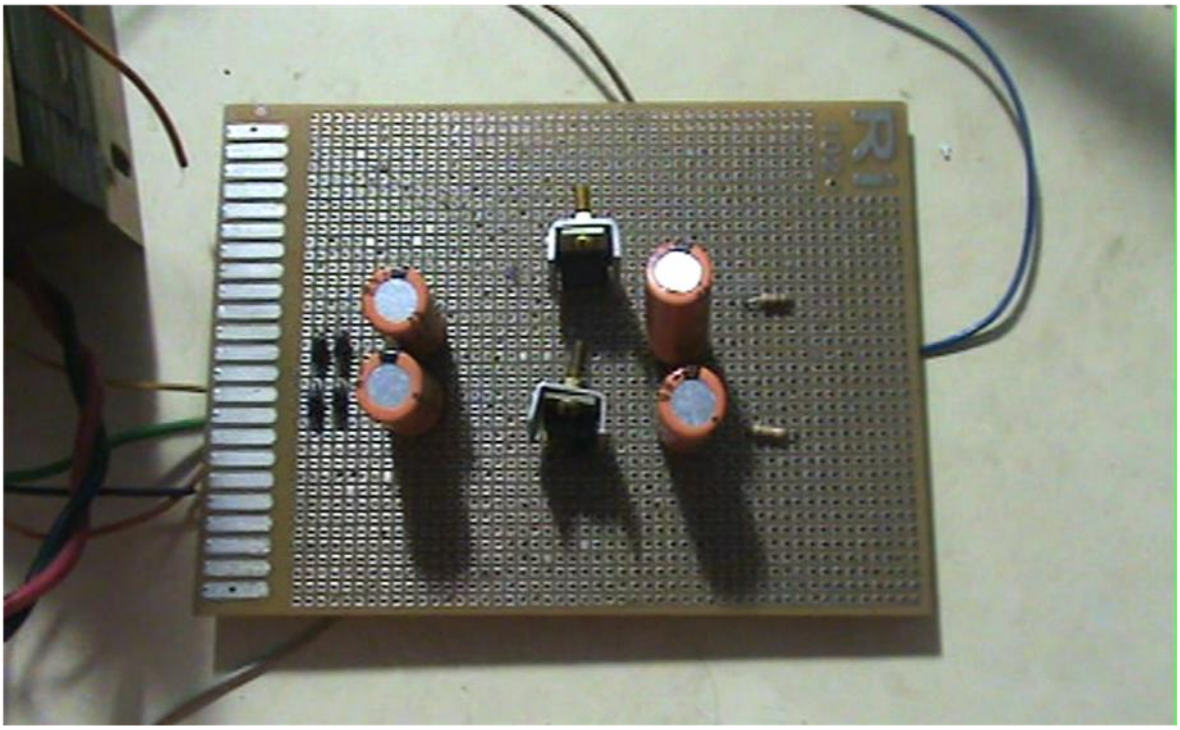


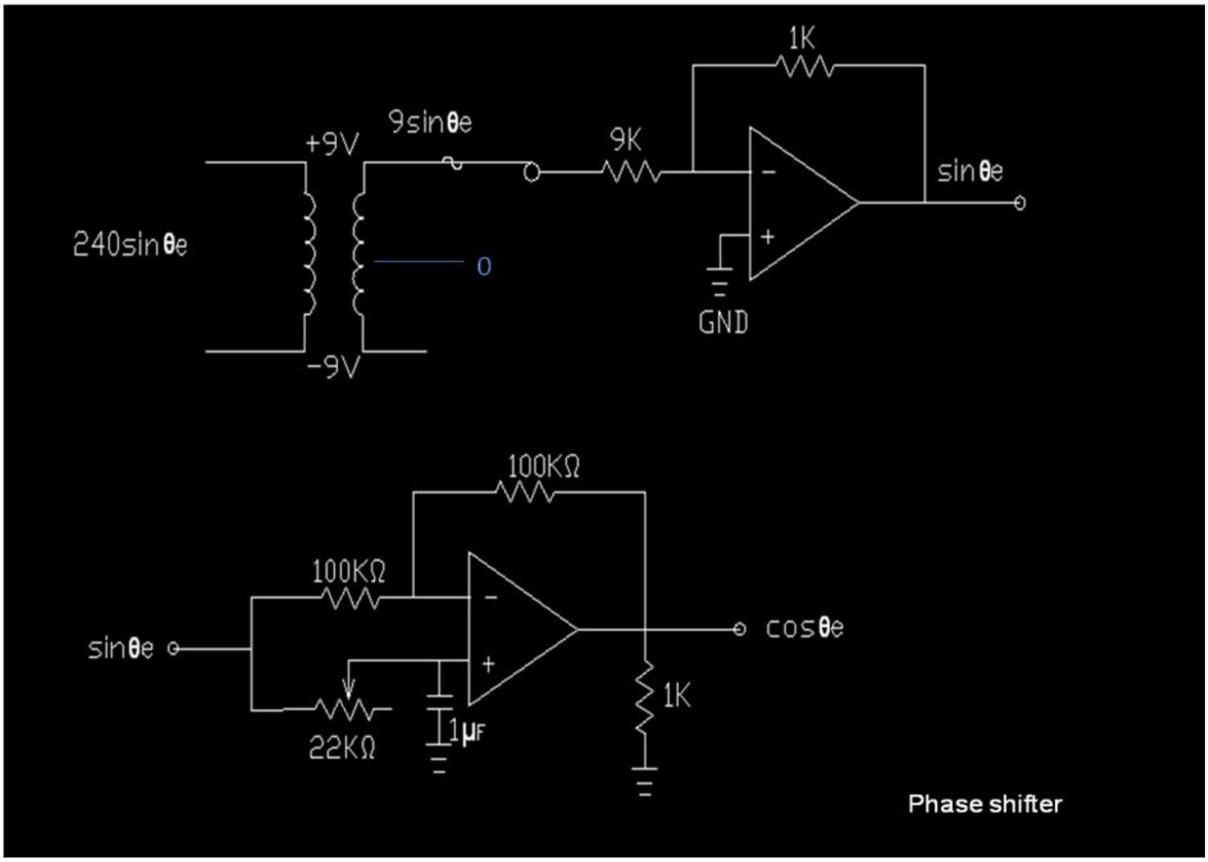
DATASHEET OF LM107



2.9Fig

Power supply circuit





phase shifter circuits

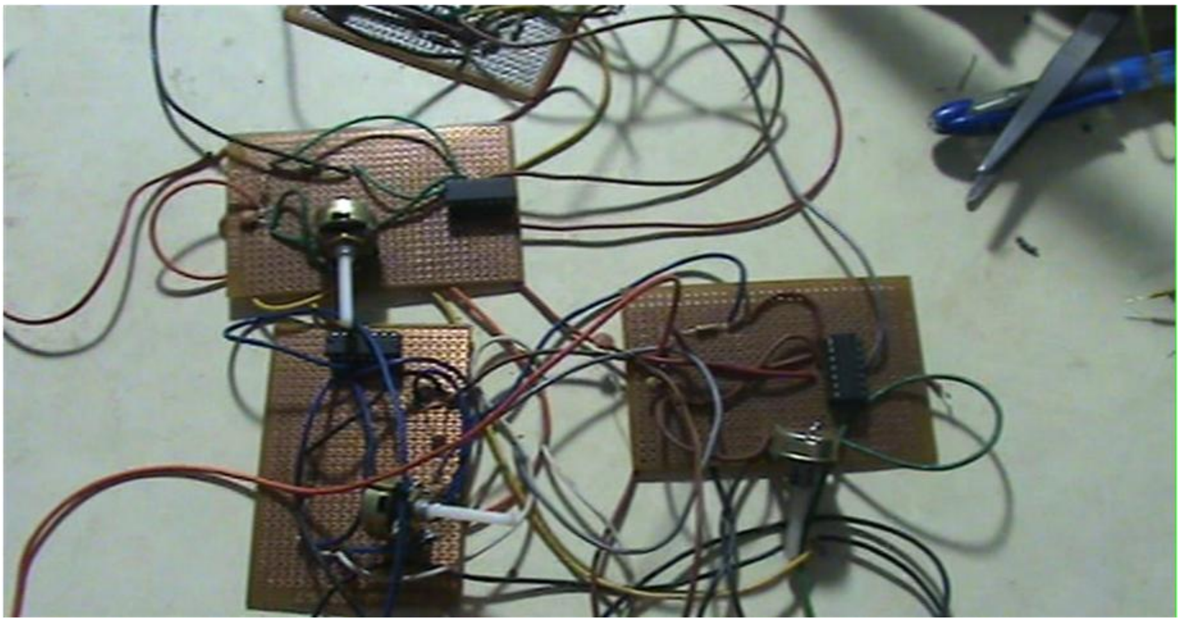
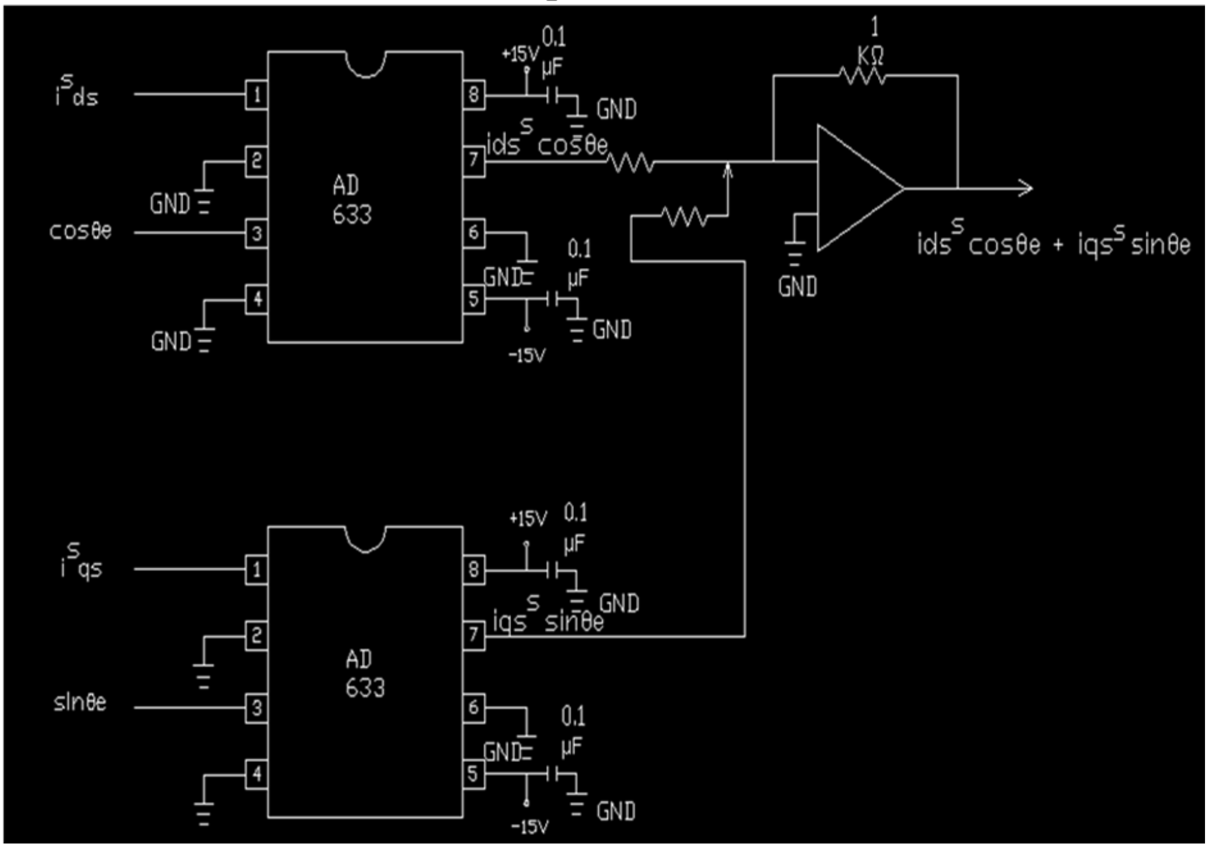
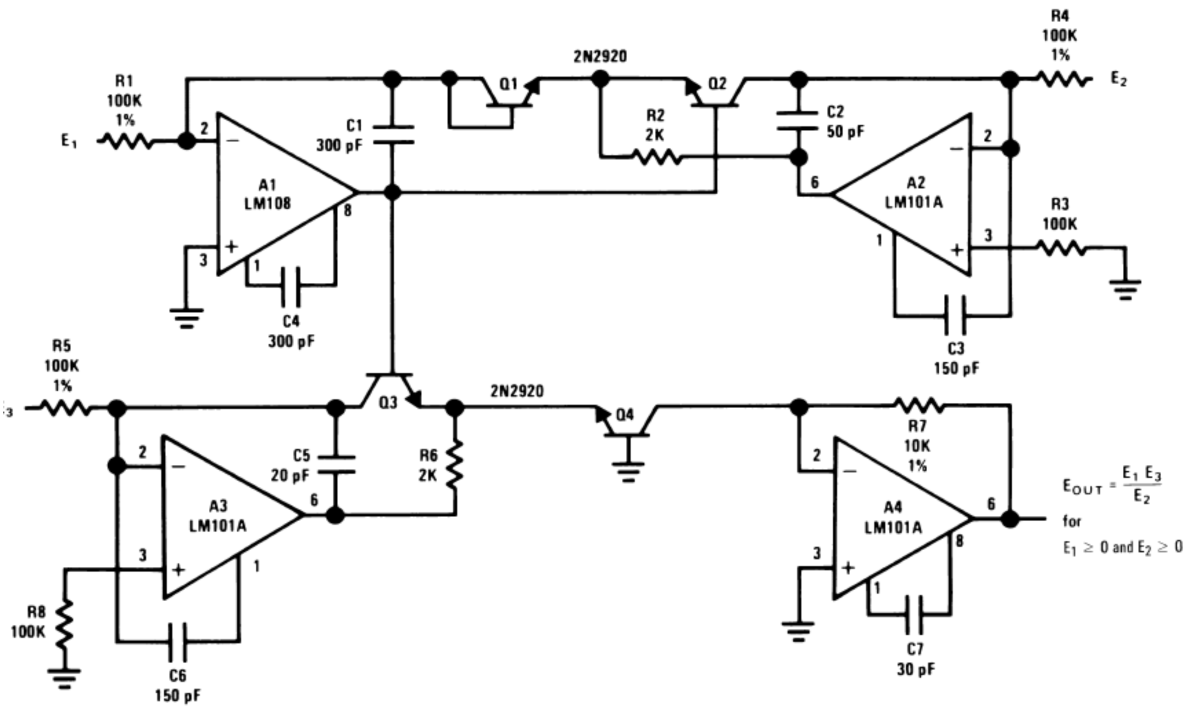


Fig 2.10

Multiplier circuit



Multiplier/Divider



Multiplier circuit

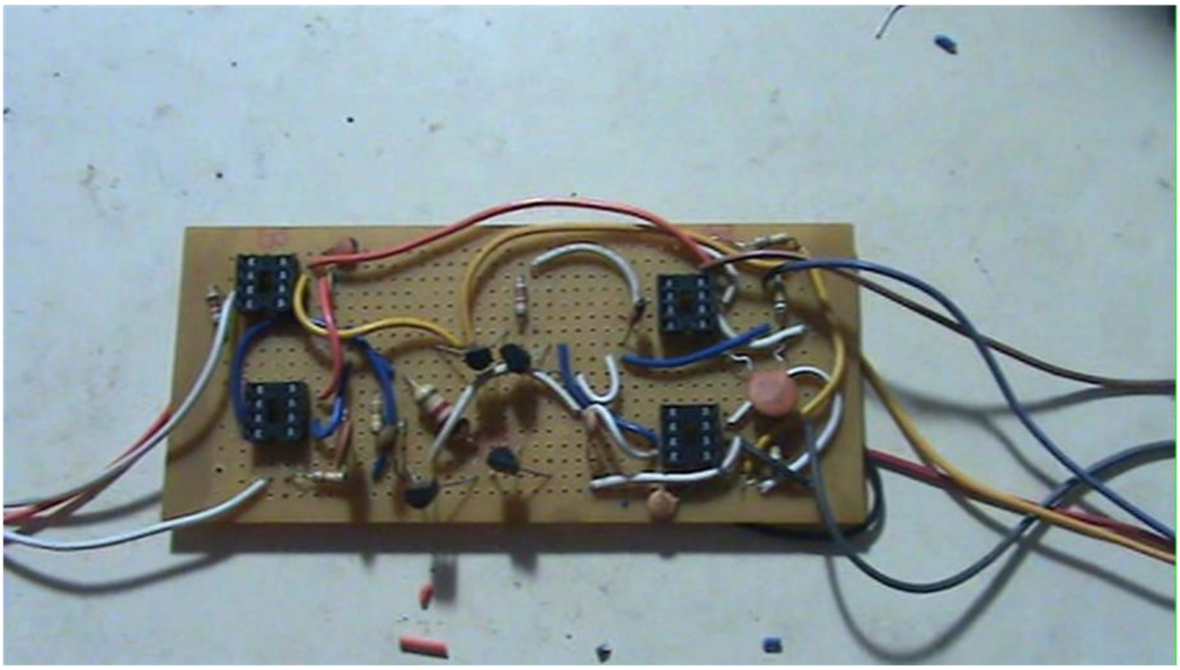
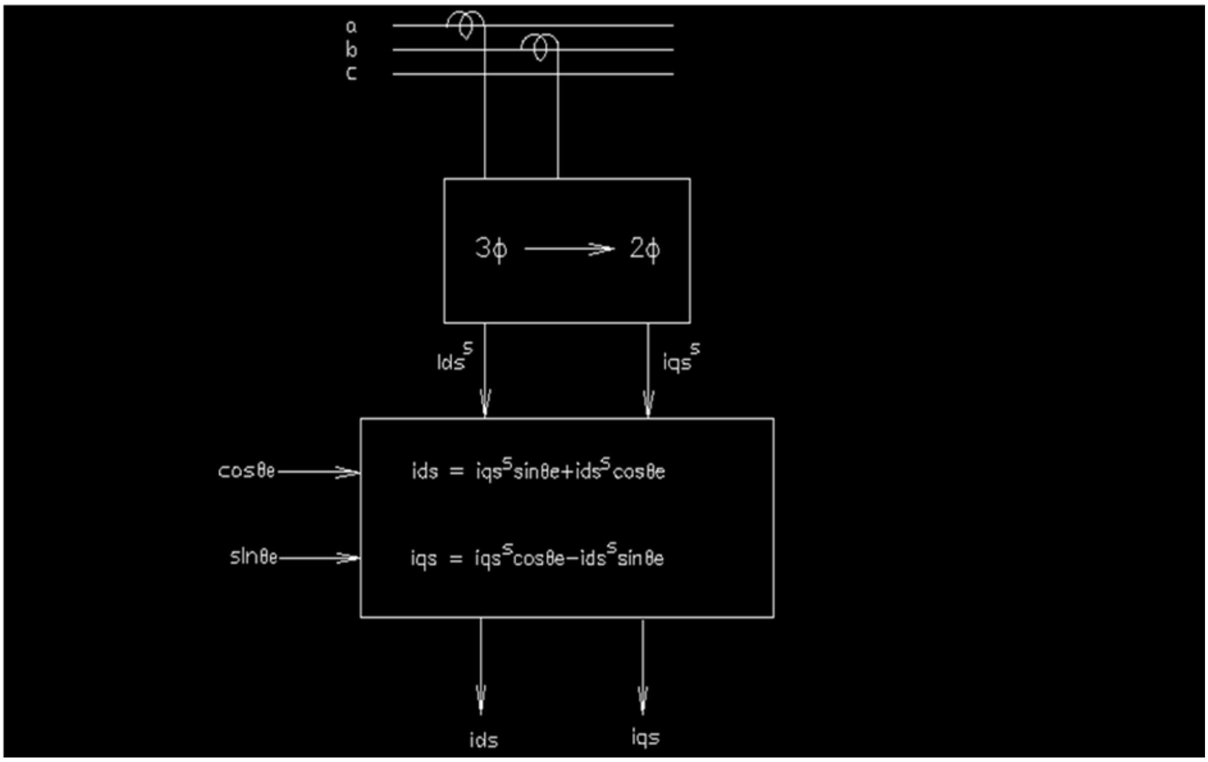
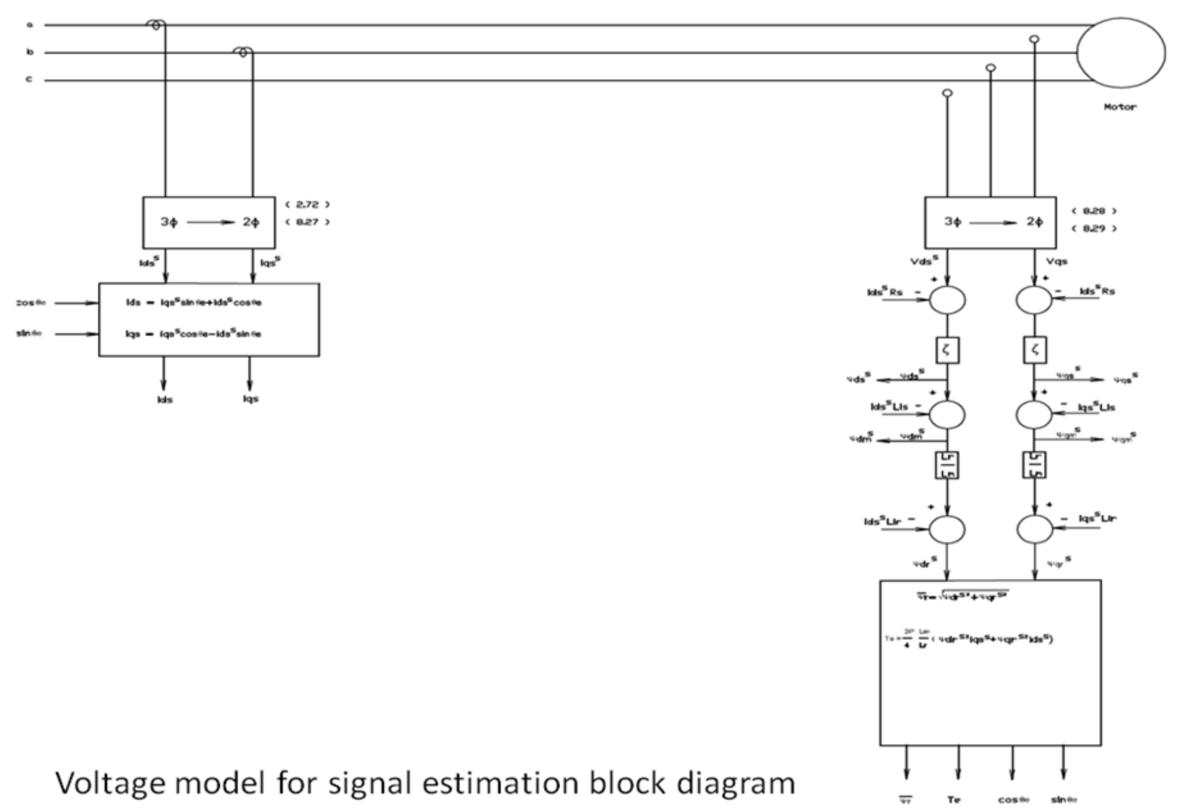
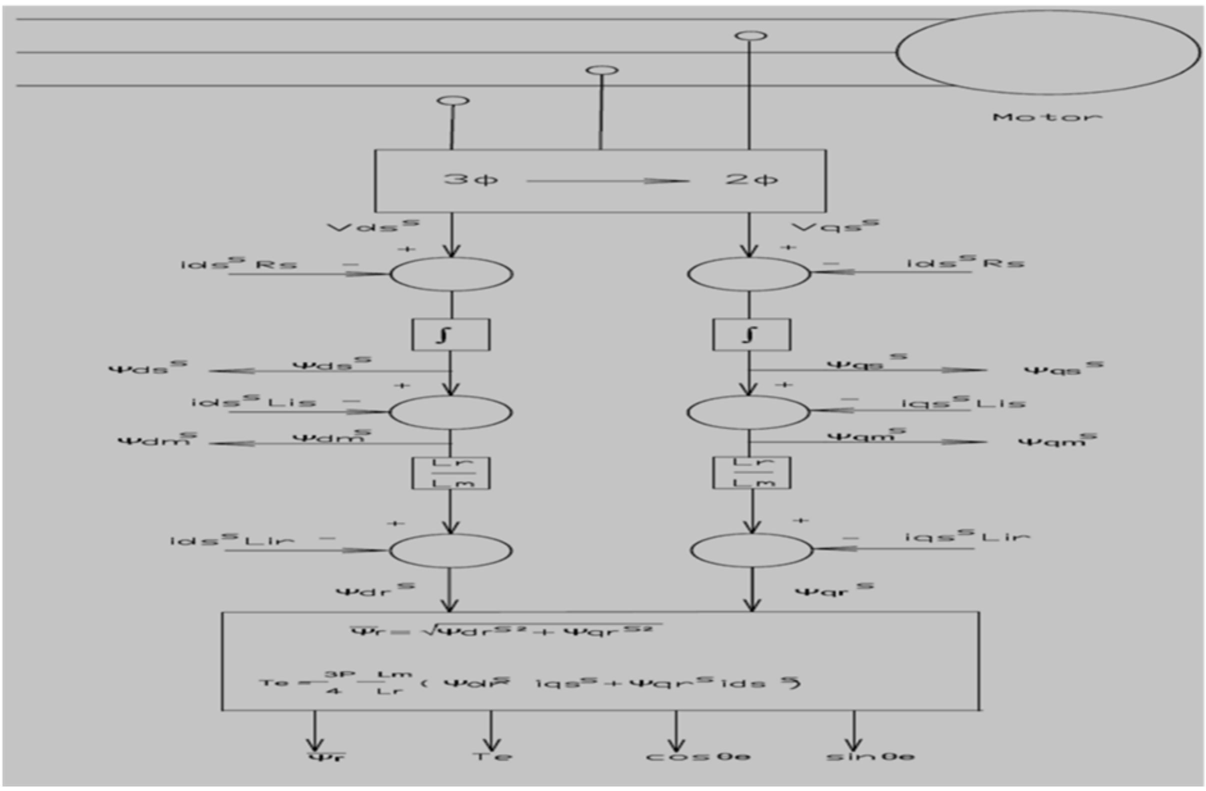


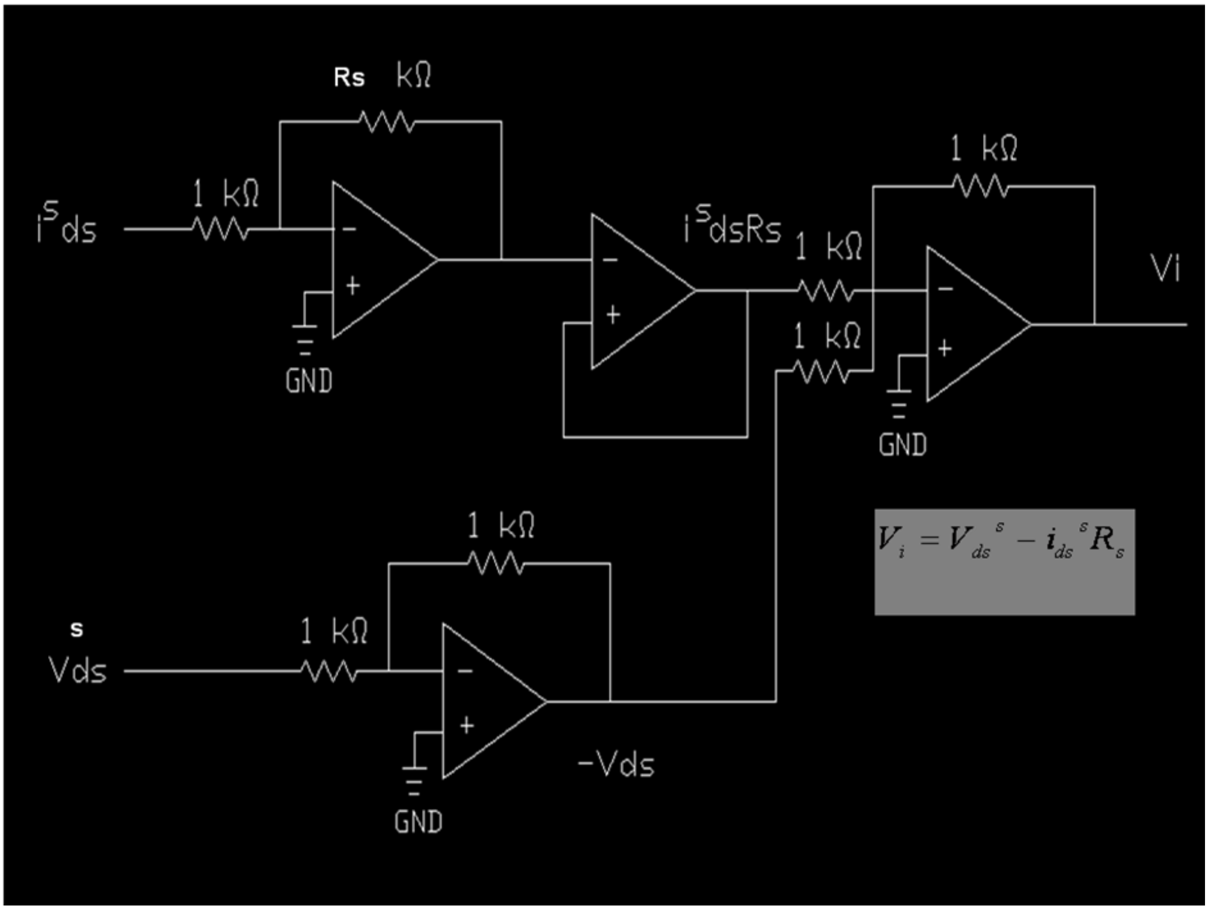
Fig 2.11





Voltage model for signal estimation block diagram





Integrated circuit

$$\psi_{ds}{}^s = \int (v_{ds}{}^s - R_s i_{ds}{}^s) dt$$

$$\psi_{qs}{}^s = \int (v_{qs}{}^s - R_s i_{qs}{}^s) dt$$

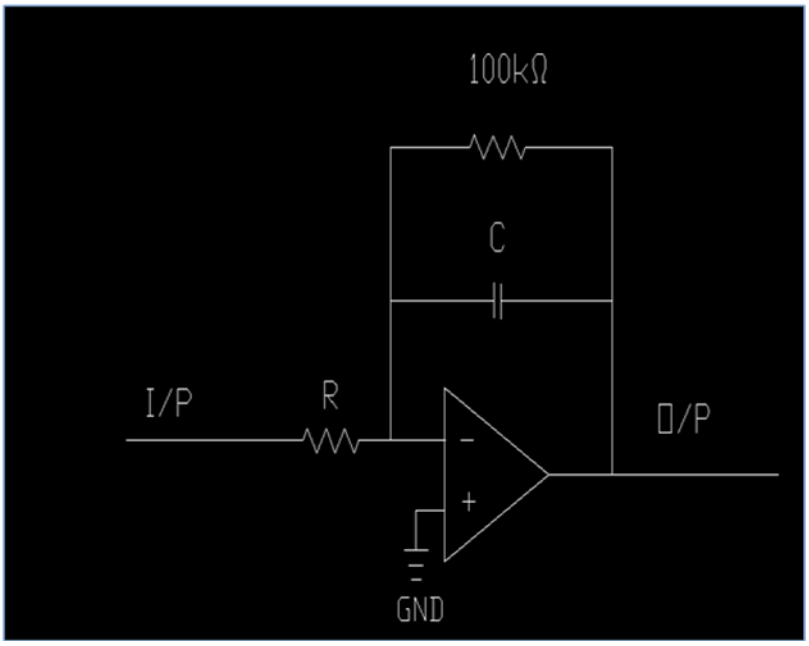


Fig 2.12

Flux vector

$$\psi_{ds}^{s} = \int (v_{ds}^{s} - R_s i_{ds}^{s})dt (1)$$

$$\psi_{qs}^{s} = \int (v_{qs}^{s} - R_s i_{qs}^{s})dt (2)$$

$$\hat{\psi}_{s} = \sqrt{(\psi_{ds}^{s^2} + \psi_{qs}^{s^2})} (3)$$

$$\psi_{dm}^{s} = \psi_{ds}^{s} - L_{ls} i_{ds}^{s} = L_m (i_{ds}^{s} + i_{dr}^{s}) (4)$$

$$\psi_{qm}^{s} = \psi_{qs}^{s} - L_{ls} i_{qs}^{s} = L_m (i_{qs}^{s} + i_{qr}^{s}) (5)$$

$$\psi_{dr}^{s} = L_m i_{ds}^{s} + L_r i_{dr}^{s} (6)$$

$$\psi_{qr}^{s} = L_m i_{qs}^{s} + L_r i_{qr}^{s} (7)$$

Eliminating i_{dr}^{s} and i_{qr}^{s} from the eq 6 & 7

$$\psi_{dr}^{s} = \frac{L_r}{L_m} \psi_{dm}^{s} - L_{lr} i_{ds}^{s} (8)$$

$$\psi_{qr}^{s} = \frac{L_r}{L_m} \psi_{qm}^{s} - L_{lr} i_{qs}^{s} (9)$$

Another form of the eq 8 & 9

$$\psi_{dr}^{s} = \frac{L_r}{L_m}(\psi_{ds}^{s} - \sigma L_s i_{ds}^{s})(10)$$

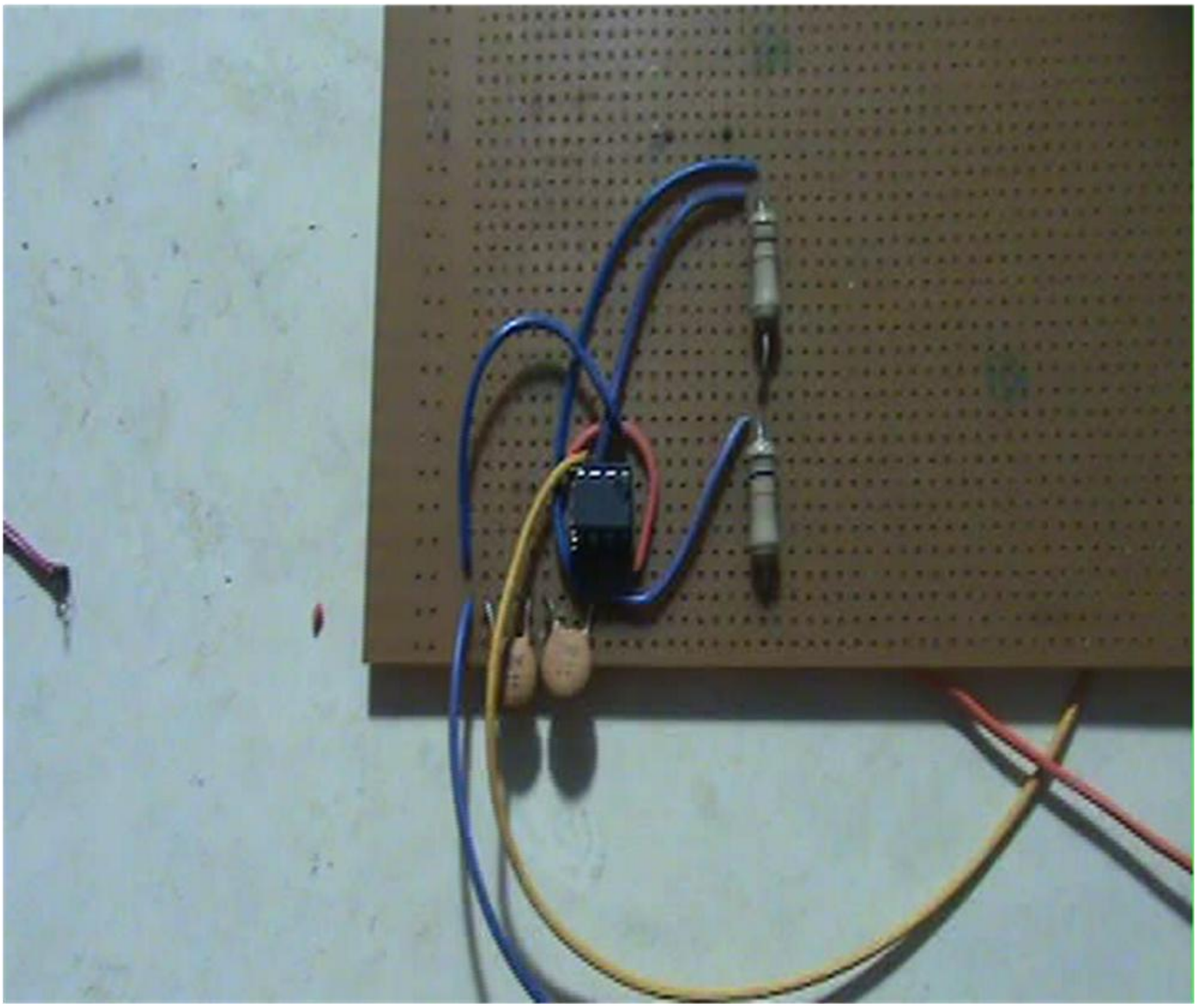
$$\psi_{qr}^{s} = \frac{L_r}{L_m}(\psi_{qs}^{s} - \sigma L_s i_{qs}^{s})(11)$$

where $\sigma = 1 - L_m^{2} / L_r L_s$

Torque

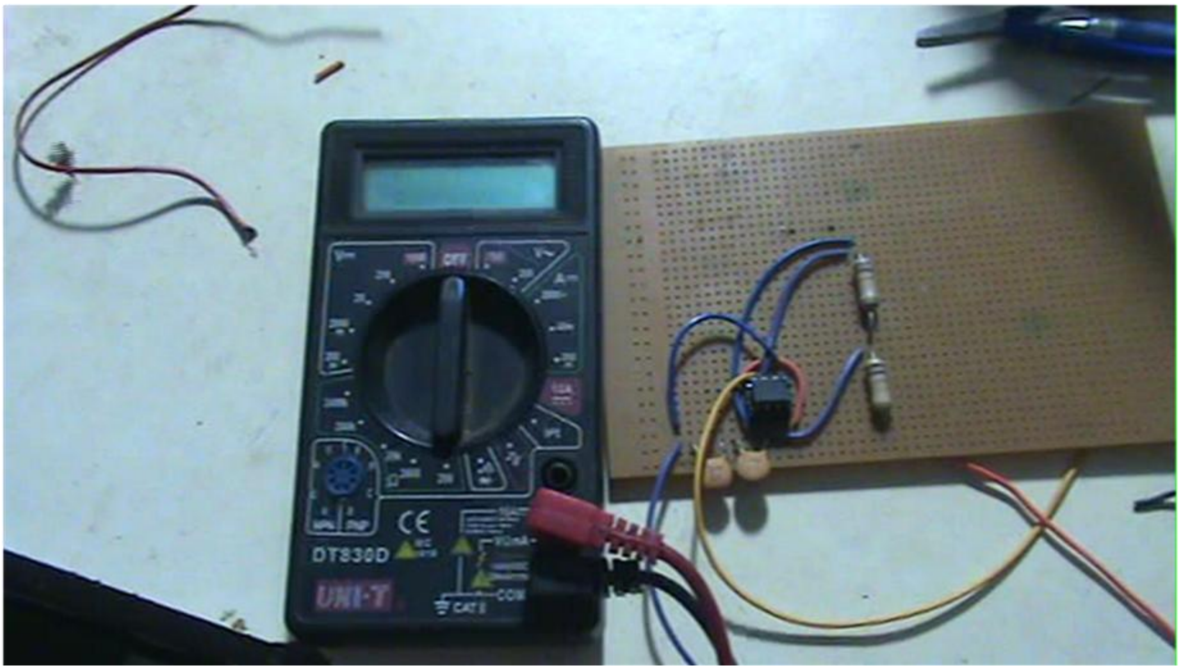
$$T_e = \frac{3}{2}(\frac{p}{2})\frac{L_m}{L_r}(\psi_{dr}^{s} i_{qs}^{s} - \psi_{qr}^{s} i_{ds}^{s})(12)$$

Voltage divider circuit



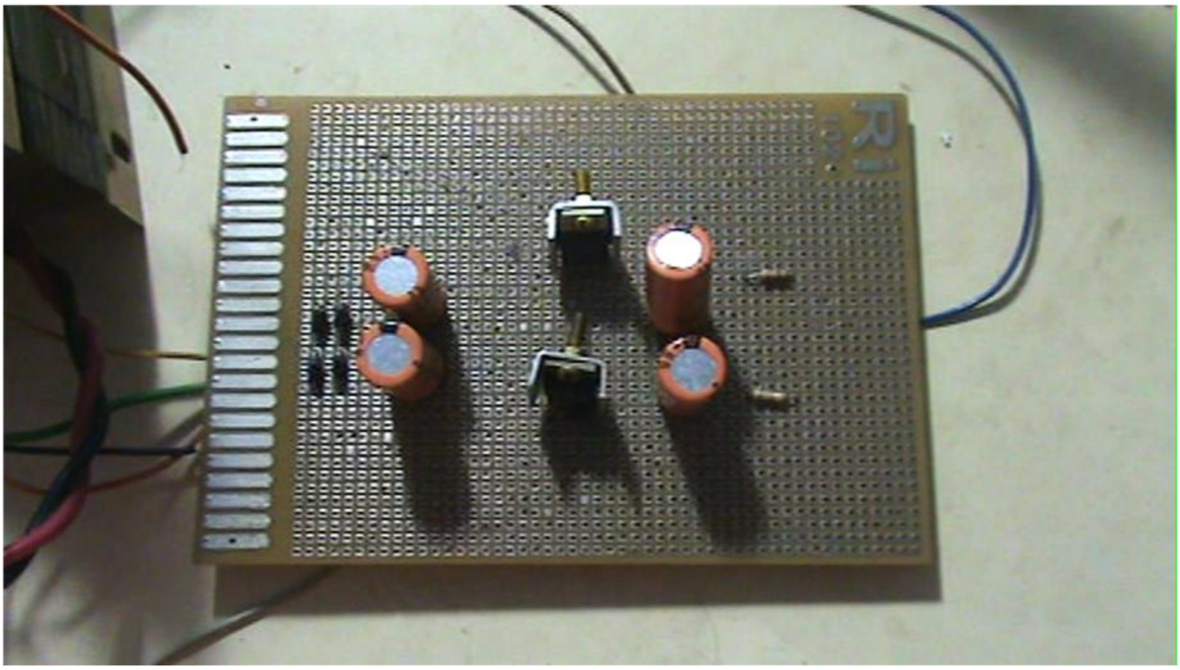
2.13Fig

Voltage divider circuit

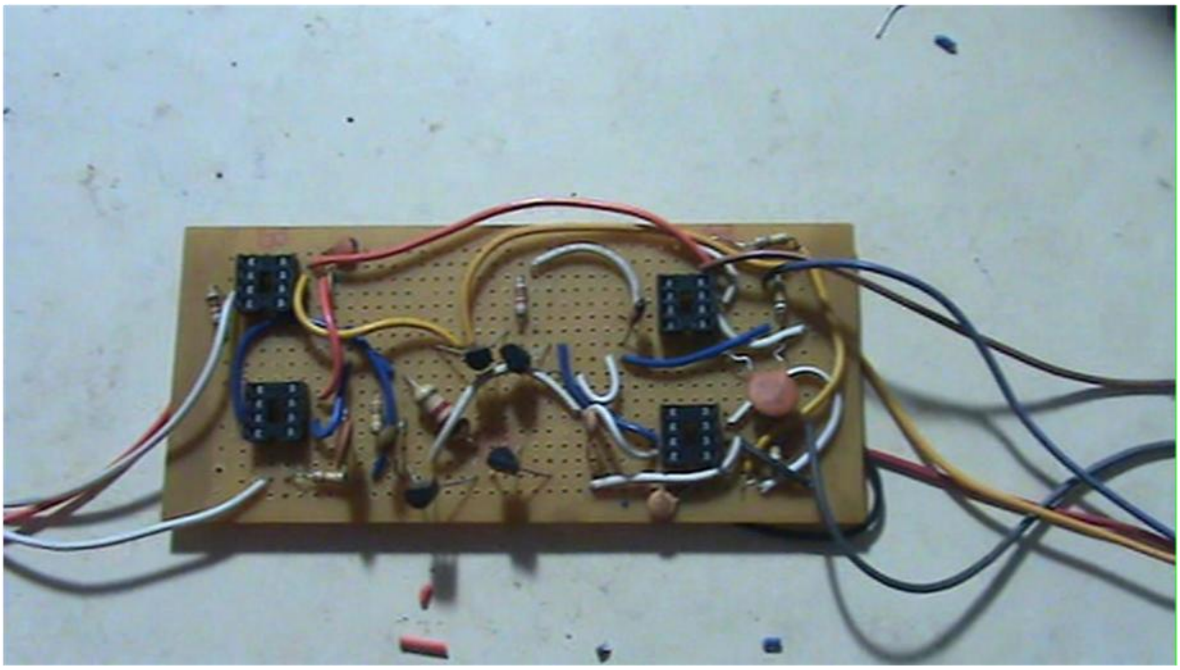


2.14Fig

Power supply circuit

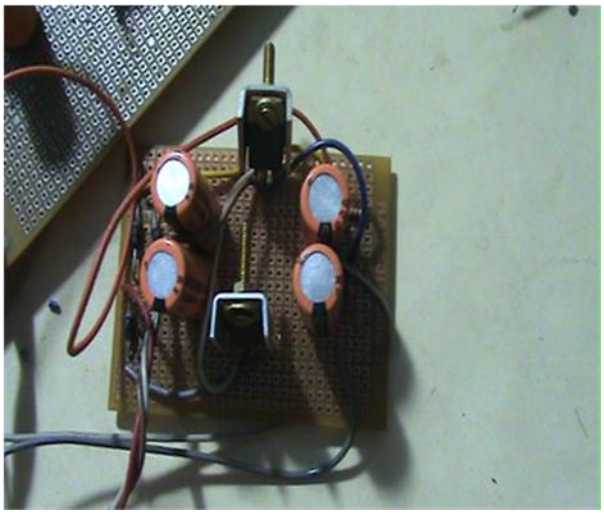


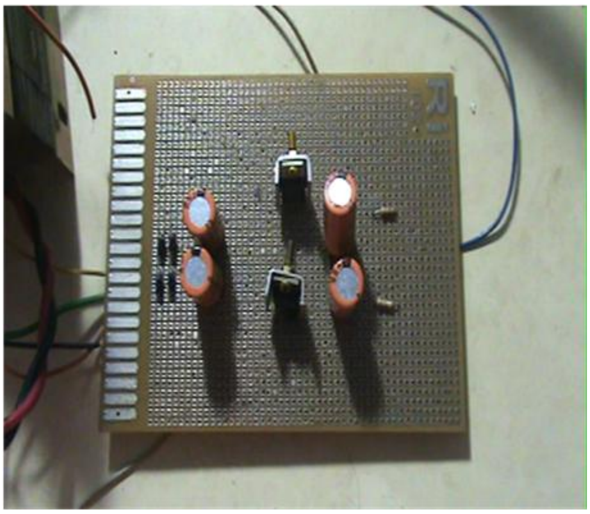
Multiplier circuit



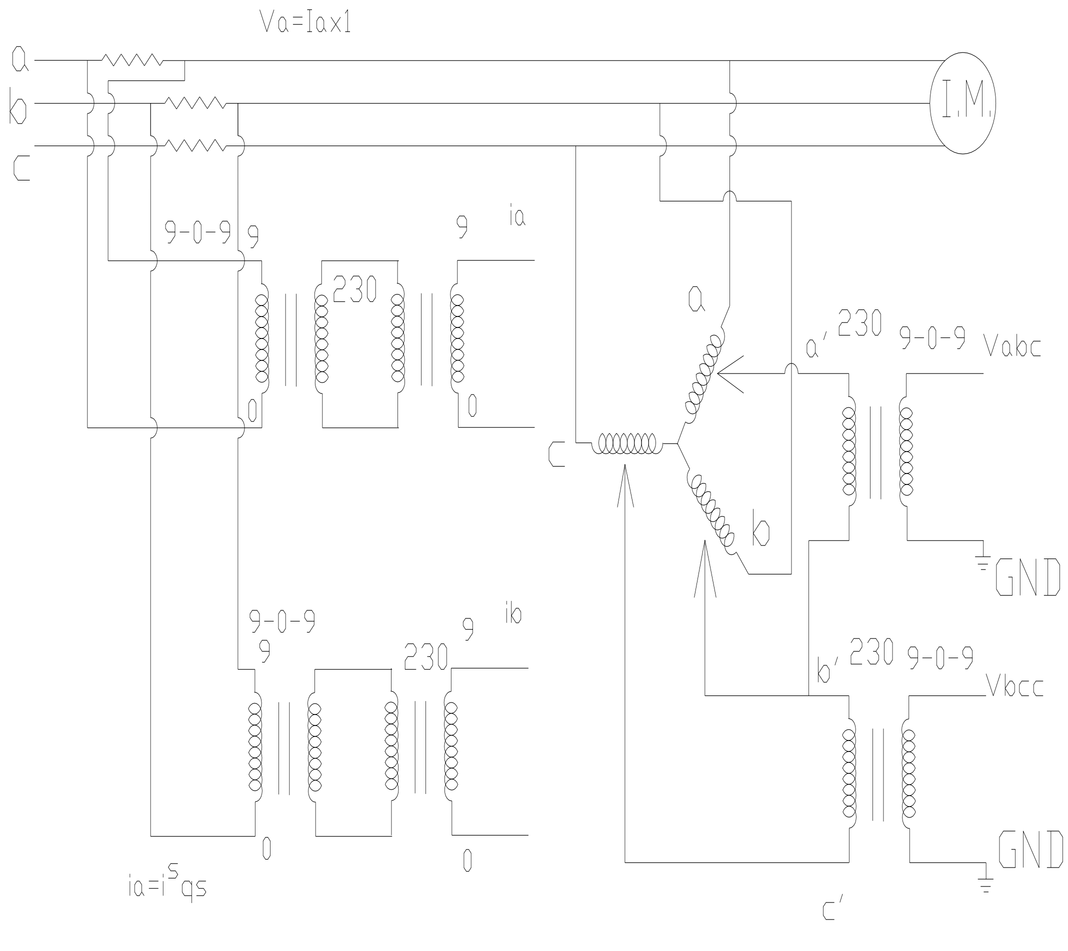
2.15Fig

Power supply circuit





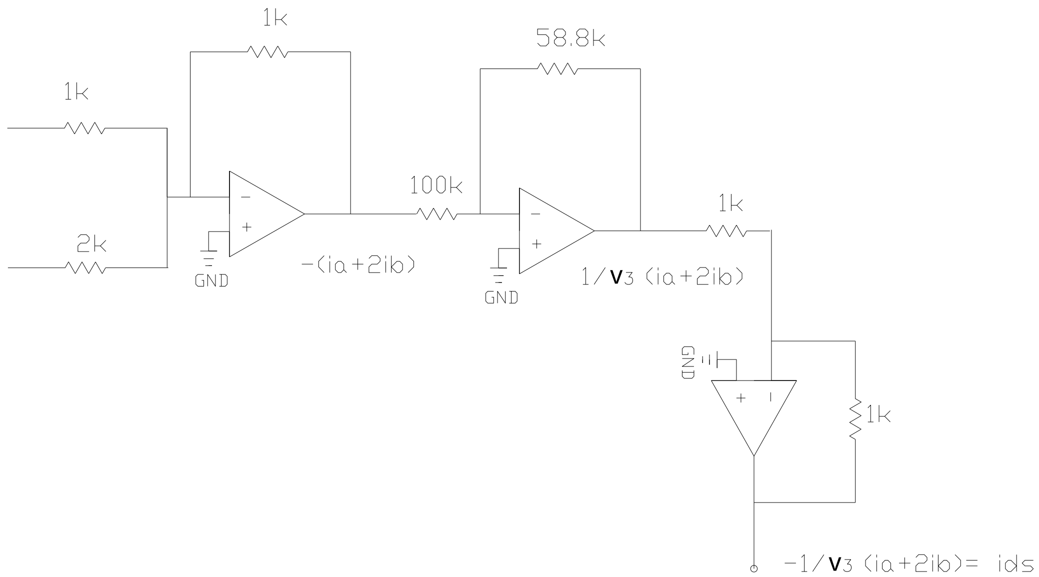
2.16 Tapped voltage from the line



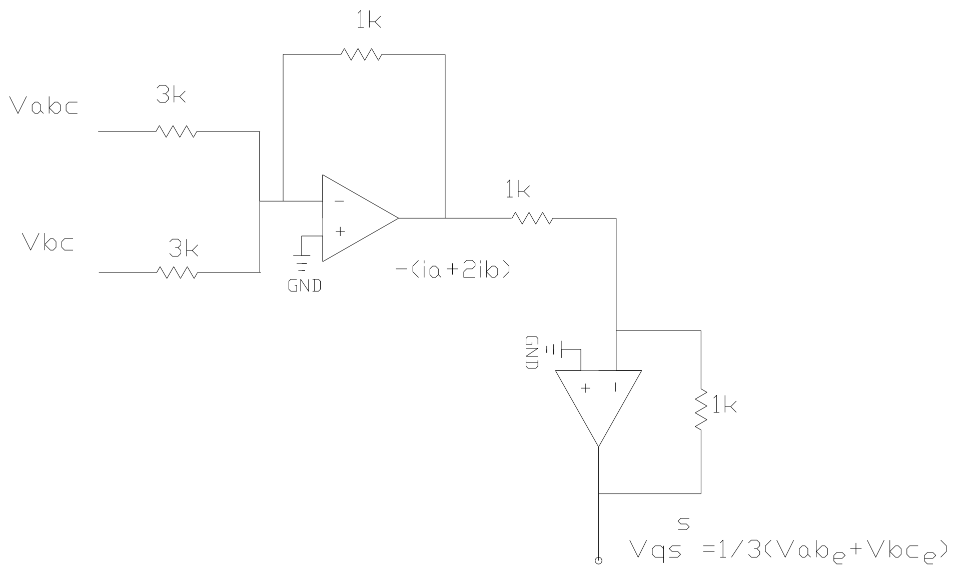
Power electronics instruments(hardware) require very less current as well as voltage to operate ,so line voltage drop up to 9volt and supply to hardware then to machine.

cs

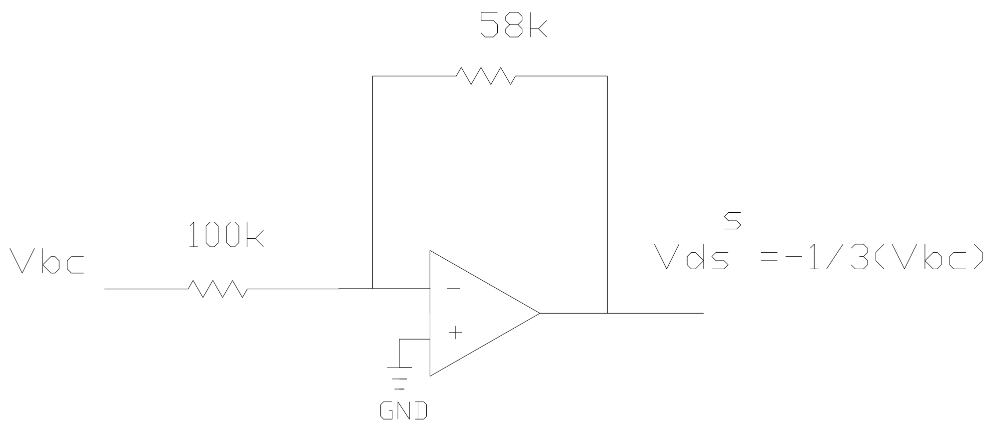
2.17 Terminal(Ids)current from the stationary frame of reference

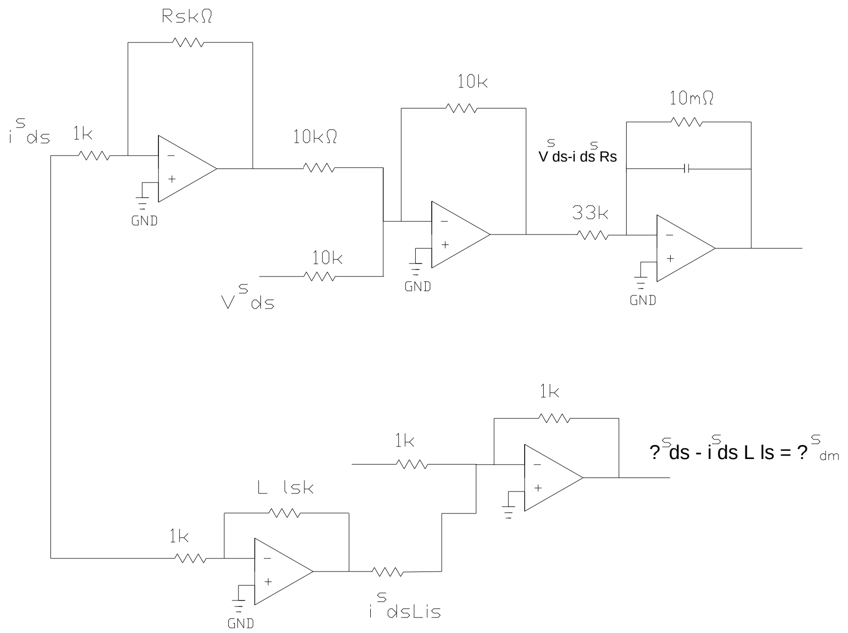


2.18 Terminal(Vds)voltage from the stationary frame of reference



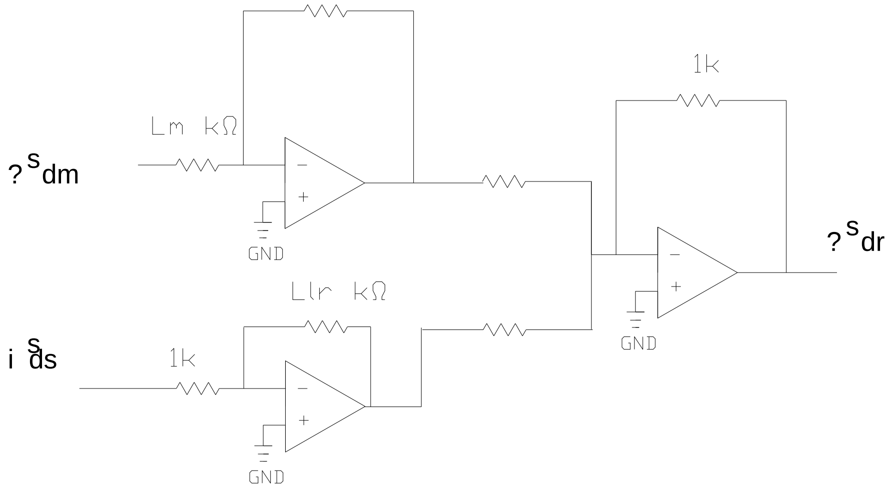
2.16Fig



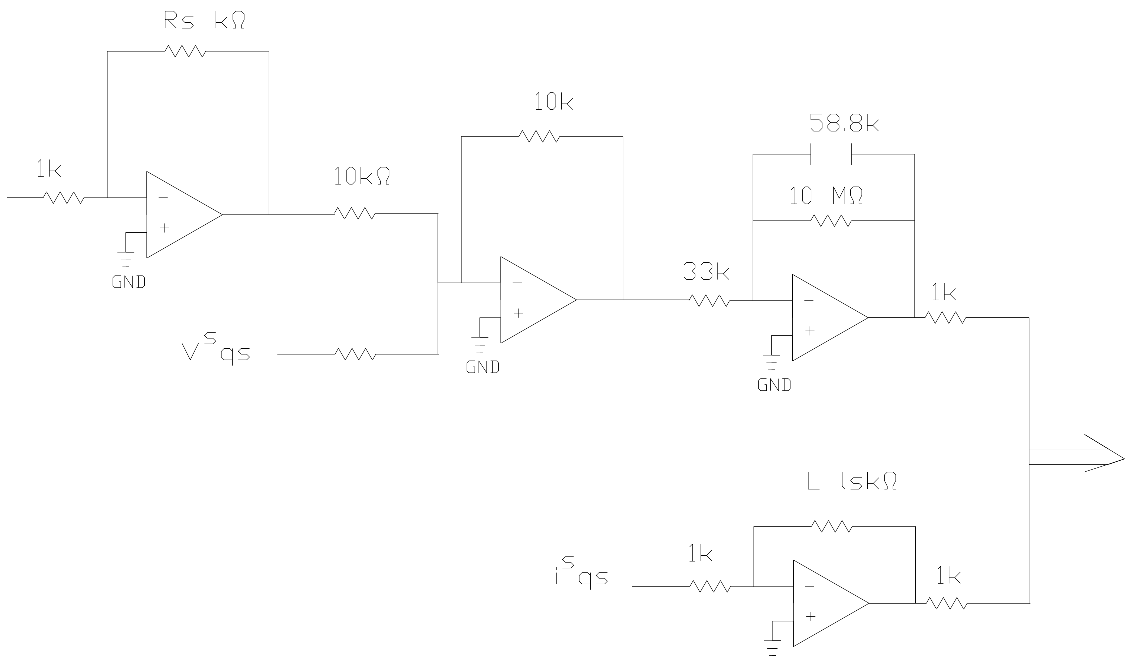


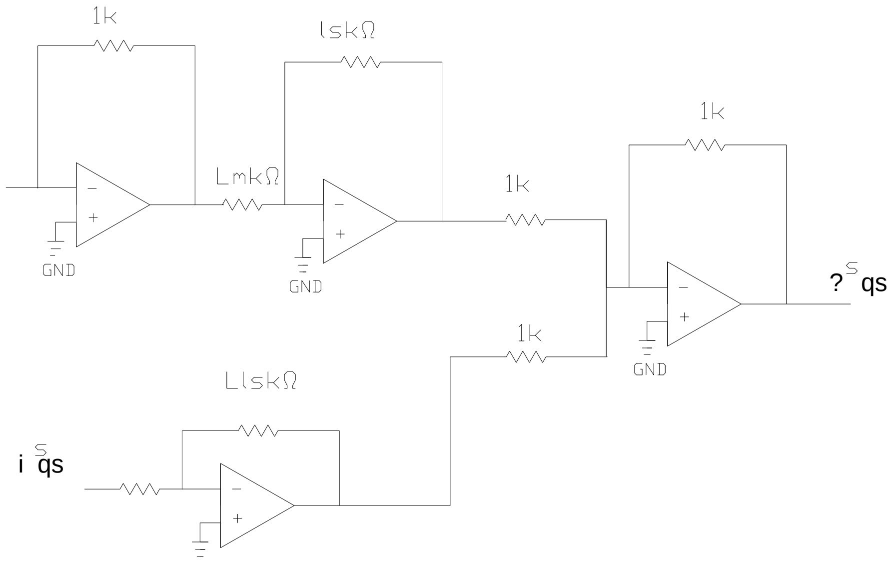
2.16fig

2.17Fig



2.18Fig





2.19fig

Conclusion

The different type of fault of grid practically made by load box in laboratory. The switching fault graphs of current and voltage are detected by storage oscilloscope. Taking all equations of induction motor we have to make the hardware circuits. Also I am going to calculate the Id and Iq.After that the control of the wind turbine taking in to account. To control of the DFIG takes place by controlling it by basically PWM control. Two converters are to be controlled by PWM technique. In DFIG control one is rotor side converter another one is grid side converter. Both active and reactive power are controlled.Total system is controlled taking reference of active power, reactive power, reference speed so on.

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