METHODS OF IMPROVING PERFOMANCE FOR ELECTRICAL POWER SYSTEMS IN IRAQ

طرق تحسين أداء أنظمة القدرة الكهربائية في العراق

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Abstract:
The main purpose in this paper to improve the performance of the electrical power systems in Iraq being developed and thereby add to its value. In recent years, performance evaluation and analysis have become increasingly for any kind of projects and for both personal and equipments safety assessment. This paper presents efficient practical methods for performance improvement and enhancement based on scientific and practical fundamentals. Power stations play important role in performance calculations, the station elements are important factors in improving the quality and security of a power system taking into account the economic problems. Failures originating within a station can create significant electrical power system disturbances. Redundancy principle can be resulted in increasing design complexity through difficult in load distribution equally between redundant systems and increased costs through additional weight and space. Full benefit is resulting of studying the connection bus-bar scheme, if the incoming and outgoing circuits are distributed evenly on the sections of bus - bars. The main reasons for grounding the neutral points to limit over voltages, different types of ground fault currents and to permit the application of suitable ground fault relaying. Transient stability enhancement is the fold of transient stability object that means suggestion of various enhancing methods to improve or augment electrical power system transient stability. Programs and graphics are executed using **MATLAB Vol . 7** and **Excel** programs.

خلاصة البحث:
أن الهدف الأساسي لهذا البحث هولتحسين الأداء أنظمة القدرة الكهربائية في العراق لكي يكون مُتُطَوَّراً وهذا يُضيفُ إِلى قيمتها. في السنوات الأخيرة لقد أَصْبَحَت دراسة وتحليل الأداء تزداد لأي نوعِ من المشاريعِ ولكلا الحسابات الشّخصيةِ وتقييمِ سلامةِ الأجهزةِ .يقدم هذا البحث طرقِ كفوءةِ وعملية لتحسينِ وتعزيز الأداء مستندة على قَواعدِ وأسس علمية وعمليةِ. إن محطات القدرة الكهربائية تَلْعبُ دورَ مهمَ في حسابات الأداء وأن عناصر المحطةِ هي عواملُ مهمةُ في تَحسينِ الجودة وأمن منظومِة القدرةِ أُخذُين في الحسبان ا لمشاكلَ الاقتصادية وأن الفشل الناجمُ ضمن أي محطةَ يُمكنُ أَنْ تَخْلقَ اضطرابات هامّةَ في منظومة القدرة الكهربائية .أن مبدأ التعددية قد تؤدي إلى زّياده في تعقيدِ التّصميمِ من خلال الصّعوبةِ في توزيعِ الأحمالِ بشكل منتظم بين الأنظمةِ المتعددة وبالتالي زيادةِ الكلفِة و كذلك زيادةِ الوزن وحيز الفضاء والمساحةَ المشغولة.هنالك فائدة كبرى من دراسة تأثير نسق قضبان التوصيل على الأداء تتحقق إذا كانت الدّوائرَ الداخلةَ و الخارجةَ تُوزّعُ بانتظام على مقاطعِ القضبان في مختلف أنواعها. أن الأسباب الرّئيسية لتأريض نقطة التعادل هو لتقيد ارتفاع الفولطياتِ ولتقيد مختلف أنواع الأعطال بسبب ارتفاع أو أنخفاض التيارات ولأختيار المرحل المناسب لتشخيص أعطال التأريض المختلفة.أن تعزيز الأستقرارية العابرة تهدف الى أقتراح طرقَ مختلفة لتحسين الأستقرارية العابرة لمنظومة القدرةَ الكهربائية. البرامج والرُسوماتِ في هذا البحث نفذت بأستخدام الحزمة البرمجية مختبر المصفوفات الأصدار السابع وبرنامج أكسل.

KEYWORDS: Improving Performance; Bus - Bar Arrangements; Transient Stability; Reactive Power Control and Harmonic Suppression Filters.

INTRODUCTION :
In this paper it can be defined the performance of an electrical power system as the capability and the quality constraint refers to the requirement that the frequency and the voltage of the power supply should remain within prescribed tolerance. A high degree of performance is one of

the major factors in the planning, good design, proper operating procedures and continuous maintenance of electrical power systems can reduce the probability of occurrence of such distribution faults. The selection of the most suitable type and rating of neutral grounding equipment should be made after preparation of fault current calculation. The performance is important and the losses resulting from outage of a large conventional generator for one day is roughly equivalent to one percent of the initial cost of the electrical machines. Possibility of simultaneous outages due to a common cause failure occurs when double circuits on the same tower structure [1].There are two approaches to improve the performance of a general system: Fault avoidance and fault tolerance. Fault avoidance is achieved by using high quality and high performance components, and is usually less expensive than fault tolerance. Fault tolerance, on other hand, is achieved by redundancy. The transportation of huge power blocks to these loads centers requires the development of the meshed extra high voltage or ultra high voltage transmission system with long and medium transmission lines, interconnected power houses and using substations for increasing performance of the power supply, greater system stability and lesser standby power plant and hence cheaper electric energy. In order to balance economy and supply adequacy in the development of such systems, probabilistic adequacy evaluation, including voltage sensitive network models and frequency variations, is strongly emphasized a complex task for planning operating staffs [2].During the initial design activity, performance improvement can be achieved in several ways such as critical and high failure rate components, duplication of functions may be feasible, careful selection of components or parts will decrease the probability of failure, the application of automatic load shedding and high speed load control devices, use of real - time rating methods, the re - conducting of overhead transmission lines with special high temperature ($75C^0$) and low sag conductors with enough tensile strength of aluminum conductor steel reinforced (ACSR) for different sizes of conductors, voltage support, reduction reactance for transmission lines, static and dynamic transmission equipment rating. Derating is meaning operating the system below its rated level, which provides an alternative means of achieving a desired goal. Highly advanced trained engineers are needed to assure a very high degree of system performance along the almost regard for the protection of our technology. Power systems contain, by design, many redundant elements strictly for increasing the assurance of continuity of power and the provision of high quality service to the consumers so redundancy is provided in many forms such as generating capacity reserve margins, interconnections with neighboring utilities and countries, additional transmission and distribution elements such as small scale generators of (25 – 75) M.W, also adding shunt compensator and simple or complex alternate supply distributors**.** Reactive power compensation is an important issue in electric power systems, involving operational, economical and quality of service aspects. The optimal location and the optimal parameter setting of thyristor controlled capacitor so as to minimize the power losses in electrical networks [3]. Grounding system behavior under transient condition is investigated by [4]. In this work, a relation between the parallel combination of the resistor and capacitor brake value and the electrical out put power of the generator is derived using the same procedure followed by [5].

This paper presents the following methods of improving performance in electrical power systems in Iraq: -

1. Key diagrams and common bus - bar network arrangements.
2. Methods of improving transient stability.
3. Methods of neutral grounding.
4. Harmonic suppression and passive filter method.

1 - KEY – DIAGRAMS AND COMMON BUS - BAR ARRANGEMENTS

In designing transmission and distribution networks supplies can be provided to different areas of the system in a variety of ways depending on the load density and system voltage level. Associated with the electrical networks themselves, various ancillary systems are needed to assist in meeting the requirement for improving performance, economy, quality and safety of supply. There are several variations of bus-bar arrangements and the following technical considerations must be taken into account, when deciding any one arrangement is required [1]:

1. The Simplicity and flexible are the keynote of the dependable system.
2. Maintenance should be easy, without interruption of supply or danger to the operating personals.
3. Alternative arrangements should be available in the event of an outage of any of apparatus.
4. The installation should be as economical as possible keeping in view the requirements and continuity of electrical power supply.
5. The practical arrangement should be suitable for future developments and future extensions.

1.1: Single Bus - Bar

The equipment connections are very simple and hence the system is very convenient to operate. Capacitive voltage transformer (C.V.T) indication is required for voltage measurement, which reduces the primary voltage. The lighting arrester **(L.A)** block implements a highly nonlinear resistor used to protect power equipment against over voltages. For applications requiring high power dissipation, several columns of metal-oxide discs are connected in parallel inside the same porcelain housing. The nonlinear V- I characteristic of each column of the surge arrester is modeled by a combination of three exponential functions of the form:

$$\frac{V}{V_{ref}} = k_i \left(\frac{I}{I_{ref}}\right)^{\frac{1}{\alpha_i}}$$

(1)

The protection voltage obtained with a single column is specified at a reference current , usually 500 A or 1 k.A rating. Default parameters k and α given in the dialog box fit the average V-I characteristic provided by the main metal-oxide arrester manufacturers and they do not change with the protection voltage. The required protection voltage is obtained by adding discs of zinc oxide in series in each column. Lightning arresters should be located to prevent a high voltage build up, it is necessary to connect lighting arrester of (1 Ω) resistance as close as bus - bar and earth and in the highest point. In case the transformers are of appreciable capacity or when it may be desirable that total capacity should not be lost in the event of a fault in near of the transformers, it is usual to provide independent circuit breaker for each transformer. Optimal capacitor allocation determines the size, type and location of capacitors to be installed on a radial distribution feeder. Shunt capacitor will reduce peak power and energy losses while minimizing the costs of investment and installation of the capacitor banks, so power factor correction must be started from distribution up to generation systems. It is useful to add a series reactor with capacitor bank to damp the energizing transients and filtering third harmonics in the network. It is necessary to add a separate series reactor to sectionalize (11) kV bus-bar, which it is useful in order to reduce and limit symmetrical three phase to ground short circuit currents, single line diagram of a single bus-bar arrangement is shown in Fig. (1) [6].

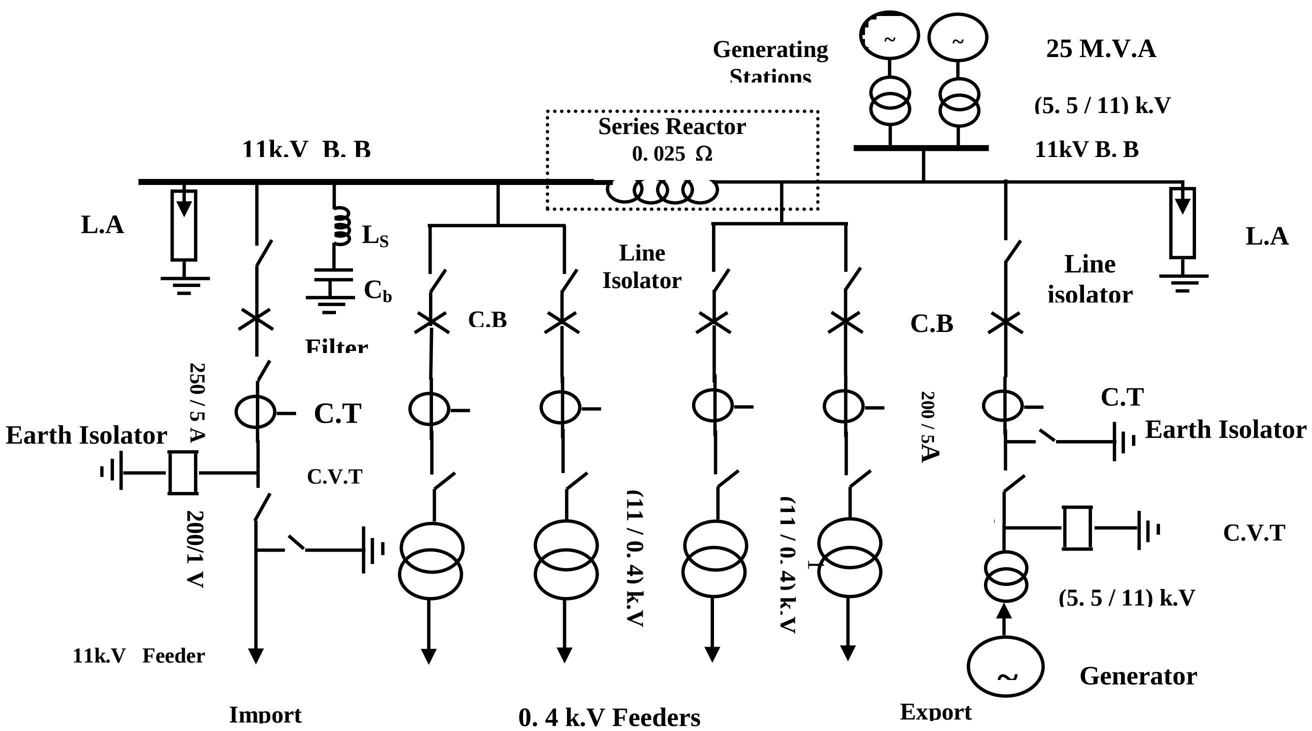

Fig. (1-a): Single Line Diagram of a Single Bus - Bar Arrangement.

The above arrangement is popular for Iraqi indoor and outdoor (11) k.V distribution sub-stations [2]. Series reactor can be calculated from the following equation:-

$$I_{3-\Phi} = \frac{3 * V_{Phase}}{x_{equavalent} + x_{reactor}} \tag{2}$$

Where: $x_{equavalent}$: is equivalent inductive reactor starting from fault point return to source in ohms.

$x_{reactor}$: is a series reactor in ohms.

The total voltage ratio for a coupling capacitor voltage transformer (C.V.T) is:

$$n = \frac{V_p}{V_s} = \frac{V_p}{V_i} * \frac{V_i}{V_s} \tag{3}$$

Where, V_p is Primary voltage side for C. V. T , V_s is Secondary voltage side for C. V. T and V_i is Specified voltage side for C .V. T in volts. This type of voltage transformer is often used in connection with line carrier communication connected through the voltage divider. The protection equipment in electrical power stations and transmission or distribution substations operate on (110V) or (48 V) D.C chargeable battery, and the communication equipments operate on (48 V) or (24 V) D.C battery. Owing to the impedance loading of the transformer there will be some ratio error on the current transformer (C.T) measurement due to the magnetizing current (I_0); while on the voltage transformer measurement due to the voltage drop depending on load current.

If, $\frac{I_{Fullload}}{I_{Secondary}} = K_n$ and $\frac{I_{Primary} - I_0}{I_{Secondary}} = K_d$ (4-a)

The percentage current ratio error ε becomes: -

$$\varepsilon = \frac{K_d - K_n}{K_n} * 100\,\% \qquad (4.b)$$

The burden of a current transformer is the load connected across its secondary terminals and is given in ohms at rated secondary current. The normal current rating of current transformer secondary has been standardized at five ampere, which are: (100: 5), (200: 5), (250: 5) (300: 5), (400: 5) and (600: 5) ampere, while standard voltage transformer are: (40:1),(20:1), (5:1), (4:1), (60: 1), (100:1),(200:1), (400:1), (600:1) and (800:1)[7]. Fig. (1-b) shows MATLAB simulation for current transformer, **Fig.** (1-c) shows response for current transformer, **Fig. (1-d**) illustrates MATLAB simulation for lighting arrester and Fig. (1-e) illustrates response for lighting arrester in over voltage makes, when lighting strike occurs on terminal of (100) km length for π - section transmission line [8].

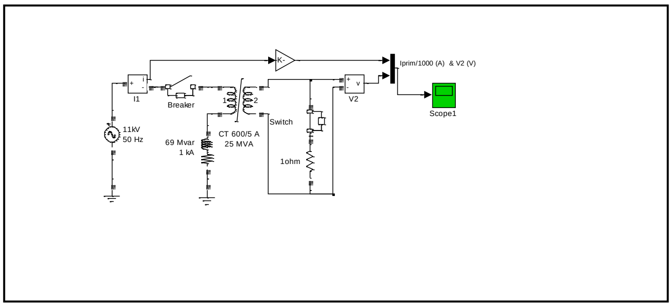

Fig. (1-b): MATLAB Simulation for Current

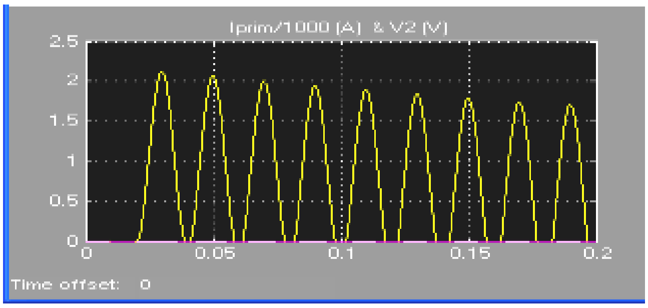

Fig. (1-c): Transient Response for Current

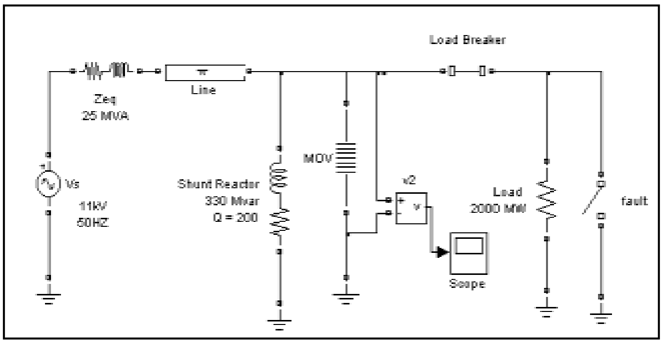

Fig. (1-d): MATLAB Simulation for Lighting Arrester

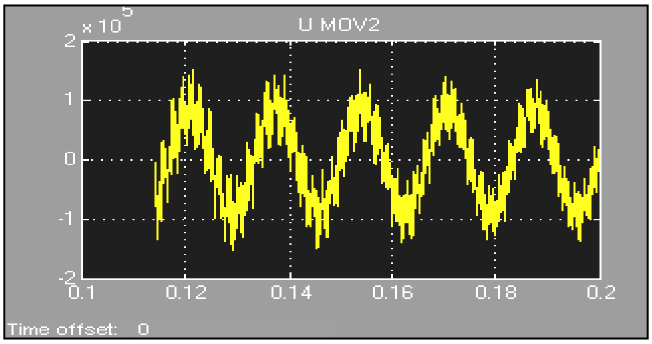

Fig. (1-e): Transient Response for Lighting

1.2: Single Bus - Bar with Sectionalized Bus - Bar

Because of cheapness and simplicity, single bus - bar is adopted with sectionalizing arrangements, where double feed is provided for any single load it is preferable to have one line circuit from each section. In this arrangement, each section behaves as a separate bus bar any outage can be confined or limited to one section of the bus bar.

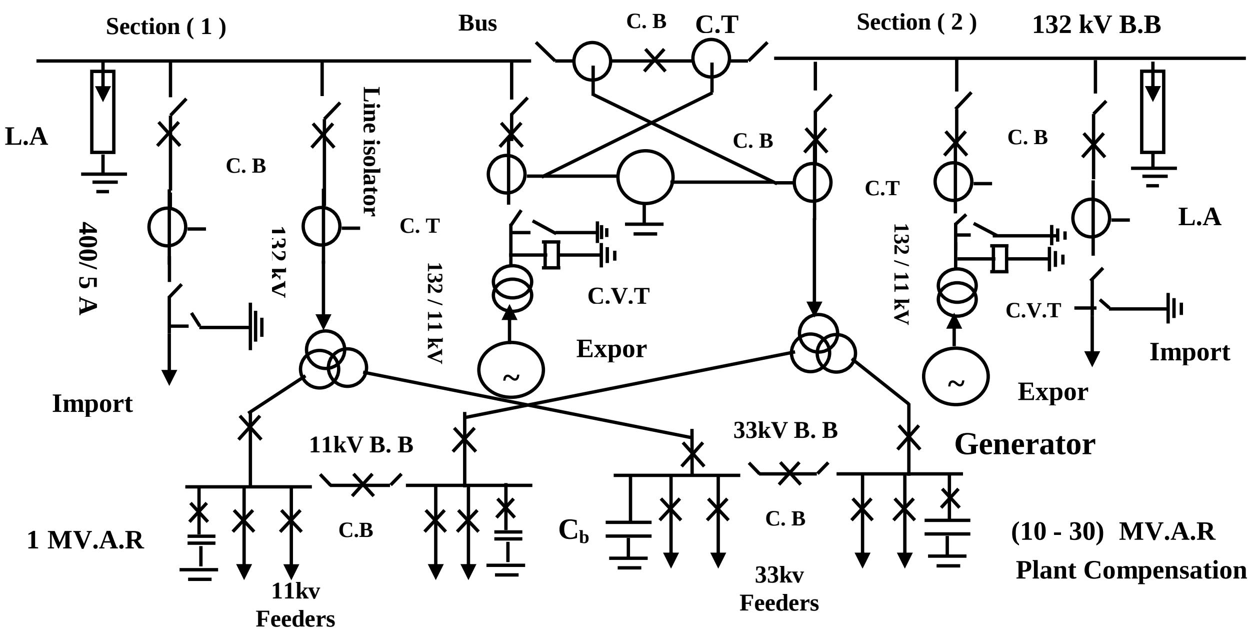

Fig. (2): Single Bus with Sectionalizing Bus – Bar Arrangement.

Full benefits a circuit breaker should be used, this will enable bus differential protection to trip only the faulty section and keep the healthy section running. The shunt capacitor banks (C_b) are used to compensate the reactive power ($I^2 * X_L$) losses in transmission impedance system and to ensure satisfactory voltage level during heavy loading conditions; consequently, power factor will be improved by means of supplying reactive power. The principal advantages of shunt capacitors are their low cost and their flexibility of installation and operation. Capacitor banks are readily applied at various points in the system, thereby contributing to efficiency of power transmission and distribution [4]**.** The voltages level along the distribution feeder are required to remain within upper and lower limits typically, within ($\pm 5.4\%$) of the rated feeder voltage level before and after the addition of capacitor bank on the 11 kV side, which has a value of (1) MV.A.R[9].

1. 3: Double Bus - Bar with Bypass Isolators

This scheme investigates the use of two identical bus - bar so that:

1. Each load fed from either bus bar.
2. The incoming feeders and load circuits divided into two separate groups, if needed from operational considerations.
3. Either bus - bar may be taken out for maintenance and clearing of all bus isolators.

These arrangements have been quite frequently adopted where the loads and continuity of supply justify additional costs. In such a scheme a bus coupler breaker is mostly provided as it enables “on load “change over from one bus - bar to another. The disadvantage of this arrangement does not permit circuit breaker maintenance, before current transformer location, which is reduce the primary current to much lower, without causing stoppage of supply power. To overcome this weak point for permitting maintenance of circuit breakers, a double bus - bar system with bypass isolators is preferable. This scheme is best from simplicity and economy. Whenever any maintenance is needed, it should be possible to afford a little shut down to make temporary jumper connection to bypass the isolators and this scheme is popular for Iraqi (132) kV transmission substations. The circuit breaker is important component for power system operation; the flexible information processing technique and software architecture usually mobile agent software apply in implementing all types of circuit breakers maintenance and repair task.

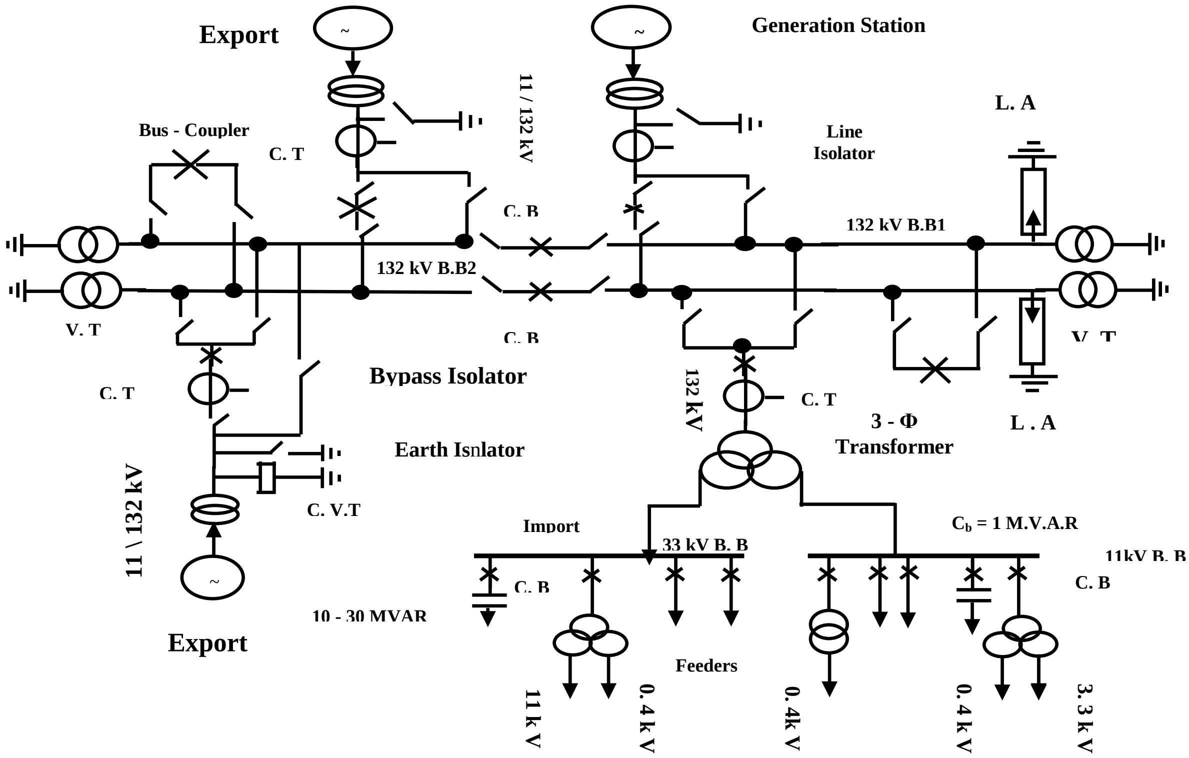

Fig. (3): Single Line Diagram for Double Bus - Bar with Bypass Isolators.

1. 4: One Breaker and a Half

In order to reduce the costs for circuit breakers to some what and still have the possibility to carry out maintenance on them without interrupting service, one and a half circuit breaker system can be used, i.e. a duplicate bus bar system having three circuit breakers for each circuit or diameter (3 : 2 = 1. 5). It should be mentioned such that any one of feeders would be connected to one circuit breaker only during the maintenance period. This scheme is very popular in many parts of the world, and considered in Iraqi (400) kV super grid. It is required to apply, on both sides of such auto-transformer, lightning arrester to avoid happening huge of voltage, which may cause danger on both sides of transformer [10]**.** For (400) k.V super grid the relationship between gas insulated switch gear and conventional switchyards is optimized about (1/50) times in installed area ,so if the conventional switchyards area is (30 * 60) m which is equal to (1800) m^2 that is **G.I.S** is 36 m^2 . The cost trends for **G.I.S** equipment are favorable; however, it is very likely that all new switchyard will be built using **G.I.S** techniques within the near future and using Sulpher Hexa Flouridi SF_6 gas to damp the electrical arc generated, instantaneously. Auto-transformer differs from isolated transformer in the lack of isolation between primary and secondary sides allow some of the transferred power to be conducted to the secondary side instead of being transferred by magnetic induction. The relative amounts of power transferred by conduction and induction vary with turn ratio; but some of the transferred power is conducted auto-transformers need less core material for each kilo volt transferred than do isolation transformers, thus auto-transformers are smaller size, lighter in weight, improved voltage regulation, lower cost and higher efficiency than isolation transformers and for these reasons auto-transformers are used in transmission substations. The impedance of auto - transformers is lower than that of isolation transformer, often as low as four percent for high tension transformers, therefore, auto - transformers tend to have good voltage regulation between no load and full load operation. Auto - transformers are usually star connected with a built in tertiary with a capacity of thirty percent of the auto - transformers K.V.A rating [11]. A fixed capacitor bank of (130) MV.A.R and inductive reactor of (25) MV.A.R on side of (11) kV side of auto - transformer.

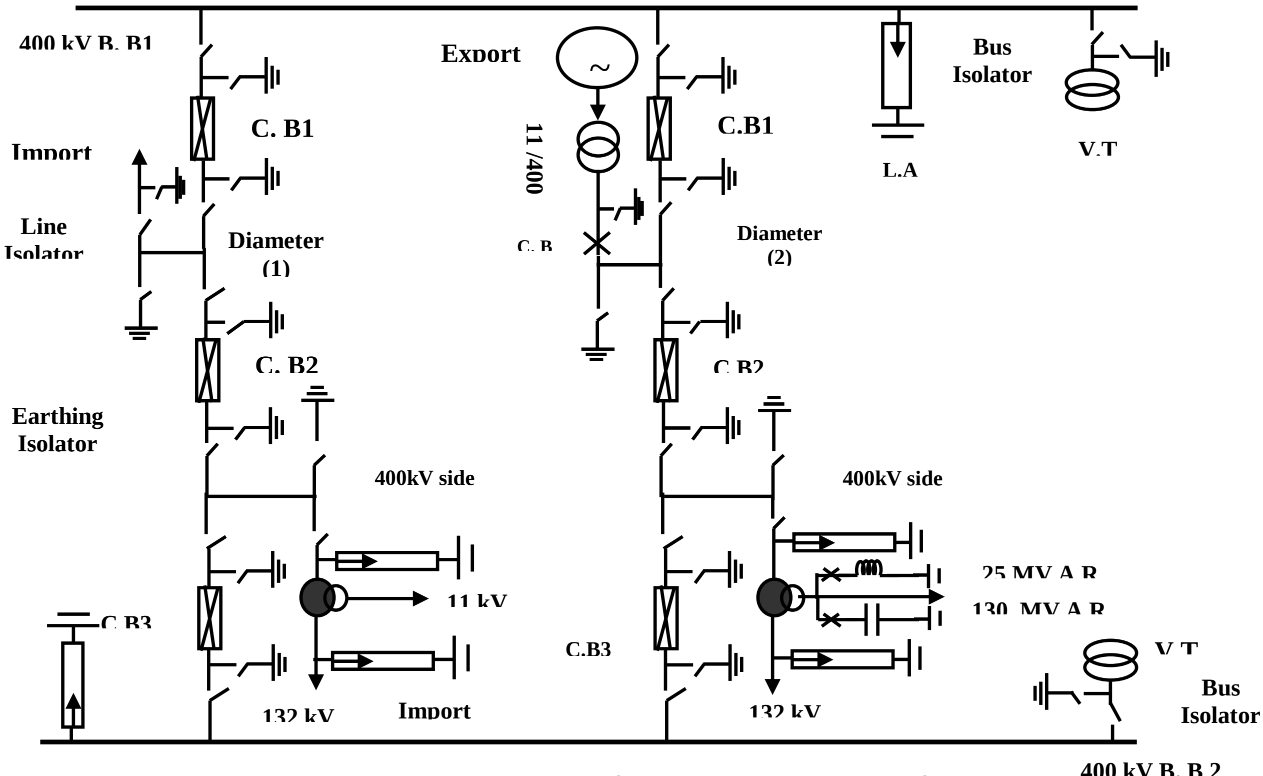

Fig. (4): Single Line Diagram for One Breaker and a Half.

2 - METHODS OF IMPROVING TRANSIENT STABILITY

2. 1: Automatic Dynamic Braking

In recent years, considerable efforts have been placed on the enhancement of the dynamic stability of power systems. Dynamic braking uses the concept of an artificial load shunted between terminals of generator and earth during a transient disturbance to dissipate the excess energy gained during fault and thereby reduces rotor acceleration. The control system for fast switching **ON** and **OFF** is satisfied for supervisory control and data acquisition of industrial processes, **SCADA** system. As the name indicates, it is not a full control system, but rather for causes on the supervisory level. It is a purely software package that is positioned on top of hardware to which it is interfaced, in general via programmable logic controllers (**PLCs). PLCs** systems have several advantages, which are flexible, faster response time, less and simpler wiring, solid state no moving parts, modular design easy to repair and expand, sophisticated instruction sets available, allows for diagnostics and less expensive [12]. Fig. (5-c) shows input and output bus network block diagram via programmable logic controllers (PLCs). The most important factors, which influence successful automatic braking, are size of dynamic brake used and timing of insertion and removal of the brake [13]. Since the excess of angular kinetic energy $(\frac{1}{2}J.\omega^2)$, gained by the rotor during acceleration period, would be dissipated through the dynamic braking, the rate of change of this kinetic energy may be used to decide when the braking should be removed. The brake should be inserted at fault removal, and removed when rate of change of kinetic energy at time (t) **(RACKE)$_t$,** which is equal to $\frac{d}{dt}(\frac{1}{2}J\omega^2)$, is zero. At this point the disturbance angular velocity ω_i in (rad / sec) is zero. In mathematical terms, the condition for brake removal is proved below:

We have an angular momentum, $M = J.\ \omega$

Also, swing equation is $\frac{d\omega}{dt} = \frac{1}{M}(P_m - P_e)$ (5.a)

Substituting Equation (4.a) in value of (**RACKE)$_t$** can get:

(RACKE)$_t$ $= P_k = \frac{\omega_i}{\omega_o}(P_m - P_e) = 0,$ (5.b)

Where: - (ω_o) is an angular velocity in (rad / sec), J is polar moment of inertia in (kg. m^2) and P_m, P_e are mechanical and electrical power in kW, respectively.

Generally**,** there are three types of braking (stabilizer) configuration elements for transient stability augmentation and enhancement which are resistor braking (Reduction of acceleration torque), capacitor braking (Rises of voltage and decreases the transfer reactance) and parallel combination of resistor and capacitor braking. Resistor braking can be effective in the reduction of acceleration torque and improving stability conditions while capacitor braking raises the voltage level and decreases the transfer reactance i.e, ($X_{br} = \sqrt{3} * R_{br}$). Shunting a resistor with a capacitor to be used as a shunt brake provides sufficient transient stability margin improvement for worst three phase fault conditions near the bus-bar as shown in Fig. (5 - a).

Table (1) shows results for dynamic braking of shunt resistor and capacitor. The difference between mechanical and electrical power in per unit for all fault stages due to the mechanical and electrical losses. Fig. (5-b) represents rotor angle curves for stable and unstable cases. A three phase short circuit current as shown in Fig. (5-a) in a parallel circuits of medium type transmission lines with series impedance parameters of (0.08 + j0. 628) Ω / km and shunt admittance parameters of (0 + j 0.003) mυ/ km. This technique is popular for Iraqi hydro electric power stations [2].

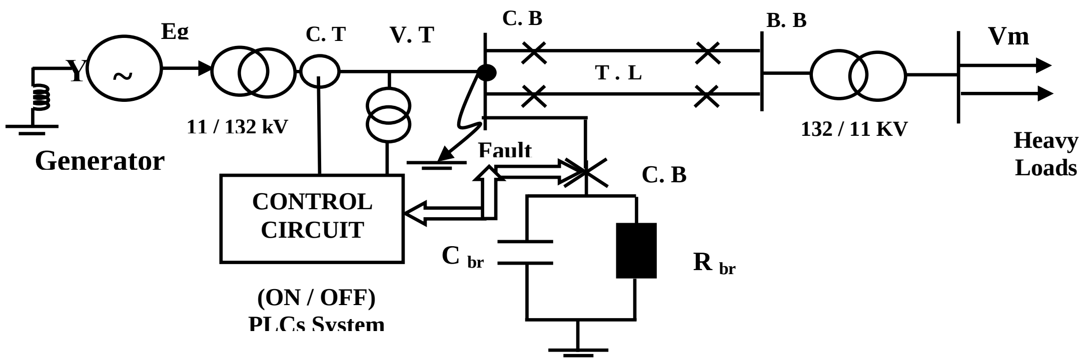

Fig. (5 - a): Dynamic Braking of Shunt Resistor and Capacitor.

Table (1): Results for Dynamic Braking of Shunt Resistor and Capacitor.

Item NO.	$P_{electrical\ maximum}$ P.U	$P_{Mechanical}$ P.U	Initial Angle Degree	Ultimate Angle Degree	Removable The Brake Second	Critical Clearing Time Second	Combination of Shunted P.U
Pre Fault	1.8	0.9	30	54.90	-	-	-
During-Fault	0	0.9	30	54.90	0.405	0.405	0.45 – j0.778
Post- Fault	1.1	0.9	30	54.90	0. 49	-	-
Fault cycle	36 Stable	37 Unstable	30	54.90	-	-	-

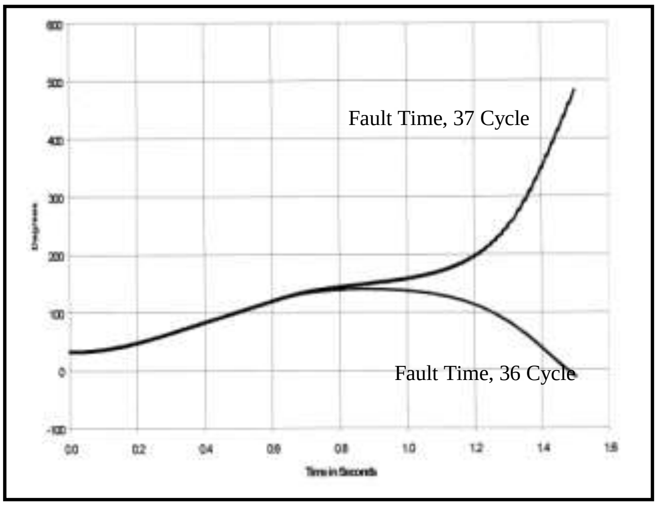

Fig. (5 -b): Rotor Angle Curves for Stable and Unstable Cases.

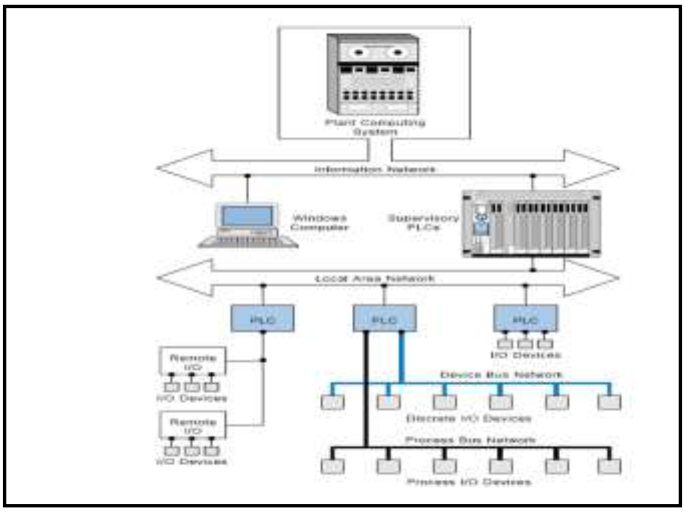

Fig. (5 -c): Input and Output Bus Network Block Diagram via Programmable Logic Controllers (PLCs)

2. 2: Single Pole Switching

When a single phase fault occurs in a power system, there is no need to interrupt services on the other two phases. Single pole switching methods have been developed, by which the circuit breakers of each phase can be switched **ON** and **OFF** independently on other two phases. The critical fault clearing time can be increased to as long as five cycles and a mechanical failure of any one pole will not propagate to other two poles, this technique is suitable for Iraqi (132 – 400) k.V sub-stations [2], while other transmission and distribution substations using conventional type of circuit breakers for three phases together to ensure balance system [14]. Figs. (6-a) and Fig.(6-b) show MATLAB simulation and transient response for electrical system with single pole reclosing circuit breaker.

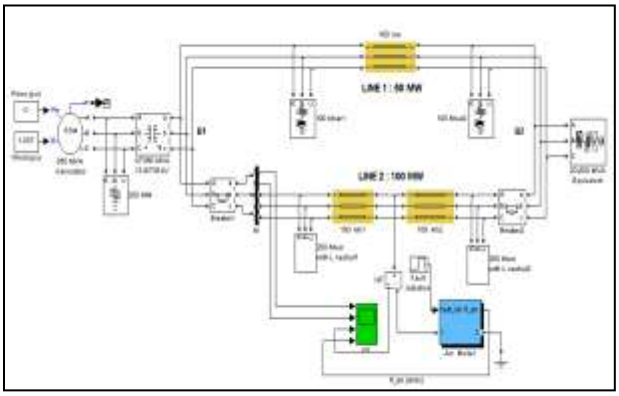

Fig. (6-a): MATLAB Simulation for Electrical System with Single Pole Reclosing Circuit Breaker

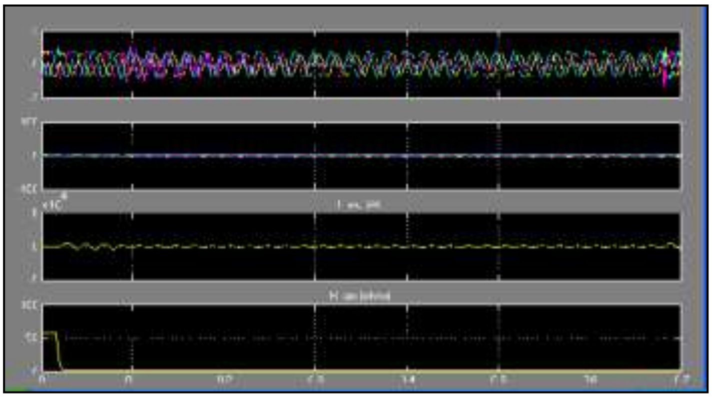

Fig. (6-b): Transient Response for Electrical System with Single Pole Reclosing Circuit Breaker

2. 3: Reduction of T. L Reactance and Compensation

The series inductive reactance of transmission networks are primary determinants of stability limits. The reduction of reactance of various elements of the transmission network improves transient stability by increasing post fault synchronizing power transfers. Obviously, the most direct way of achieving this by reducing the reactance of the transmission lines, which are determined by the voltage receiving and sending rating (V_R, V_S), as shown in equation (6)[15].

$$P_{Transfer} = \frac{/V_{Recieving}/ * /V_{Sending}/}{X_{Tranfer} - X_{Capacitor}} * \mathrm{Sin}\,\delta \quad (6)$$

Where δ is power angle in degree between sending and receiving end voltages, which is usually very small value measured in electrical degree.

1. Series capacitor compensation of transmission lines when a fault occurs in one circuit of a double circuit transmission system and the faulted section is switched **OFF**, temporary insertion of a series capacitance can enhance the power transferability, and hence the transient stability of the system can be improved. It is found that a capacitance should be inserted when the generator is over the synchronous speed and should be removed when the generator is under the synchronous speed. Series capacitor has the following usual locations considered [16].

- Mid-point location of the line has the advantage that the relaying requirements are less complicated, in addition, short circuit current is lower, and however, it is not convenient in term of access for maintenance, monitoring and security state. If the compensator can vary its admittance continuously in such away as to maintain middle voltage (V_{Middle} = E), then in the steady state the line is sectioned into tow independent halves with power transmission characteristic given by $P = \frac{2.E^2}{XL}\sin\frac{\delta}{2}$ (7)

From diagram shown in Fig. (7-a), consists of a nonlinear resistor of zinc oxide (ZnO) limits the voltage across the capacitor bank during a fault and re - inserts the bank immediately on termination of the fault current, single spark gap room (G), which bypass the capacitor bank when the capacitor voltage exceeds a set value, usually about three to four times the capacitor rated voltage, which is provided as a backup over voltage protection for the resistor. The damping circuit (D) limits the discharge current and absorbs the capacitor energy, upon detection of gap current. When the current returns to up normal state, the circuit breaker is open, thereby reinserting the capacitor into the line at time of (200 - 400) msecond [171].

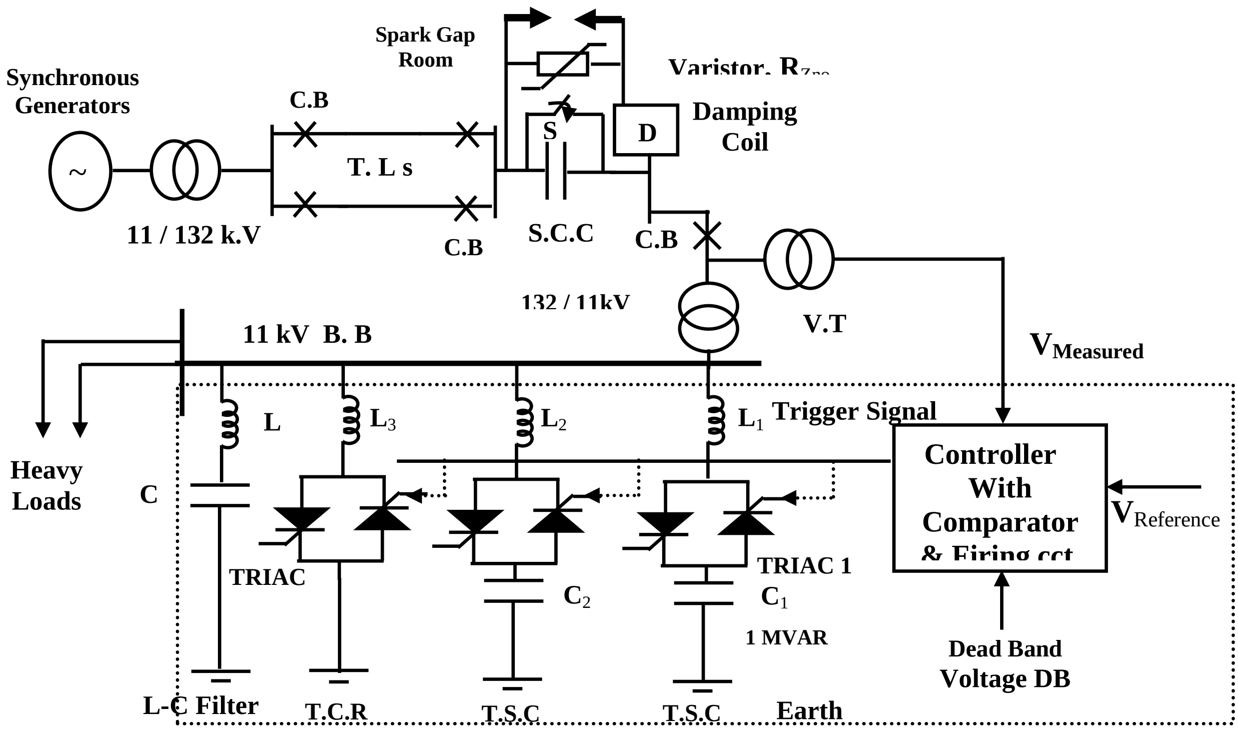

Fig. (7-a): Effect of Series and Shunt Capacitance with Thyrister Switch Capacitors.

2- The response of power system to a disturbance, such as feeder trip or a step change in the load, must be instantaneously and network quantities such as bus voltage must be adjusted. So, static var compensated (**S.V.C**) is necessary for maintaining voltage stability limit by regulating of bus voltage and adjustable shunt susceptance after (300) msecond. A power Thyristor switched capacitor (T.S.C) scheme consists of a capacitor bank split up into appropriately sized units, each of which is switched **ON and OFF** by using thyristor switches. Each single-phase unit consists of a capacitor(C) in series with a (bi-directional) thyristor switch and a small inductor is used to limit switching transients, to damp inrush currents and to prevent resonance with heating losses of the network. Series (L C) across the capacitor banks used for filtering third harmonics in network. The shunt susceptance is divided into several parallel units and varied by controlling the number of units in conduction. The bus voltage (V) is controlled within the range ($V_{Reference} \pm$ DB), where DB is the dead band voltage about ($\pm$ 5.8) %. The thyristors switched capacitor requires a control system, which determines the firing angle; consequently, the power factor will be corrected and controlled [18]**.** In power Thyristor switched capacitor the change in number of units in conduction state can make every half cycle, so this form of control, harmonics dose not generate. Fig. (7-b) illustrates MATLAB simulation for static var compensation in electrical networks, Fig. (7-c) shows transient response for phase voltage, reactive power and number of tyrisror switch capacitor**,,** while Fig. (7-d) shows MATLAB simulation for capacitor series compensated transmission system, Figs. (7-e) and (7-f) illustrate transient response before and after series capacitor compensation [8]**.** Total line reactance in positive-sequence is (105.6) Ω and the capacitor reactor required for (40) % compensation is (42.24) Ω or series capacitance is (62.8) uF, if fault occurs at first phase. Lighting arrester used for over voltage protection level required to protect the capacitors at (2.5) times of the nominal capacitor voltage that is (298.7) k.V. From power system calculation in this study, when adding the shunt capacitors to control the voltage level and reduce the amount of power loss in transmission lines by (50) %, which represents the difference before and after shunt capacitor compensations, while the power losses in Iraqi networks is (10) % of total electrical power generated. Table (2) shows values of inductive and capacitive reactances for static var compensated at 50 Hz

Table (2): Values of Inductive and Capacitive Reactances for SVC

Inductive Reactance, XL_{Shunt}	2. 42 k Ω	7.707 H
Series Reactance, XC_{Series}, 40%	42. 240 Ω	75.396 μf
First Shunt Capacitor, XC_1	14.520 k Ω	0.219 μf
Second Shunt capacitor, XC_2	7. 260 k Ω	0.438 μf
Third Shunt Capacitor, XC_3	4. 840 k Ω	0.657 μf

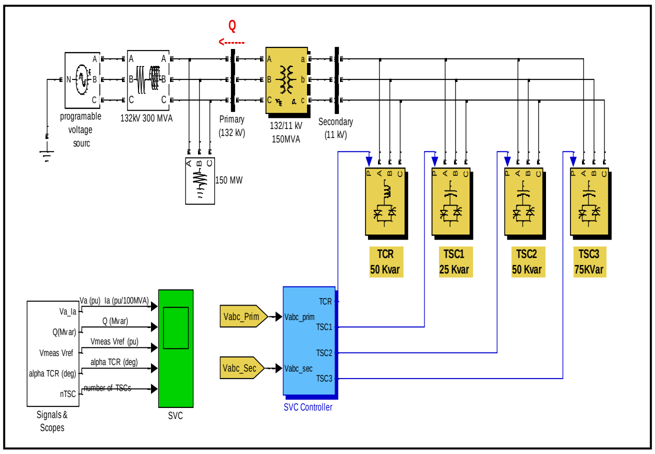

Fig.(7-b): MATLAB Simulation for Static Var Compensation in Electrical Networks

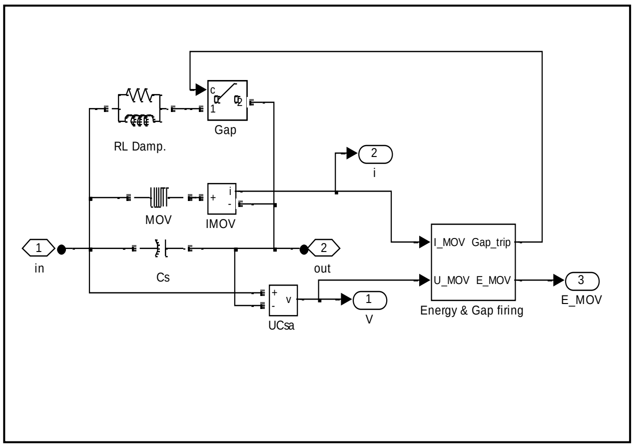

Fig. (7-g): MATLAB Simulation for Lighting Arrester and Spark Gap for Series Capacitor Compensator

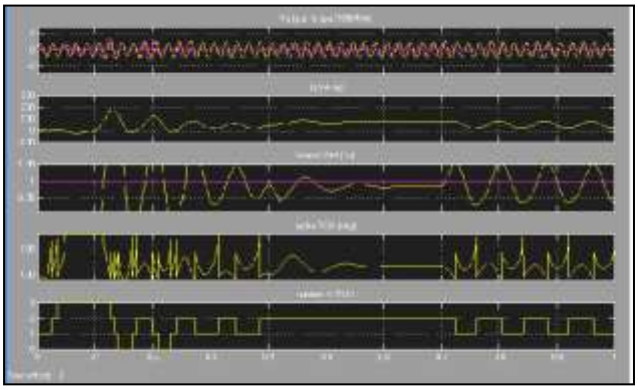

Fig. (7-c): Transient Response for Phase Voltage, Reactive Power and Number of Tyrisror Switch capacitor.

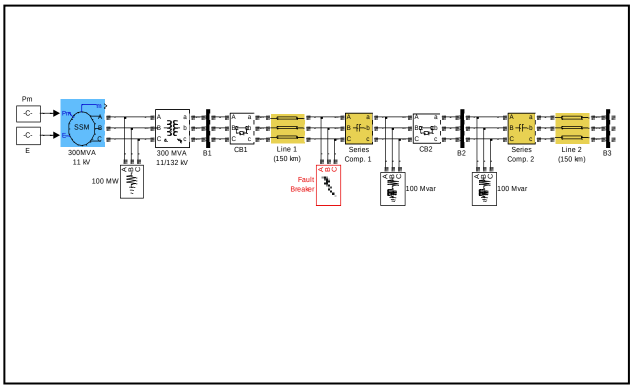

Fig. (7-d): MATLAB Simulation for Capacitor Series Compensated Transmission System

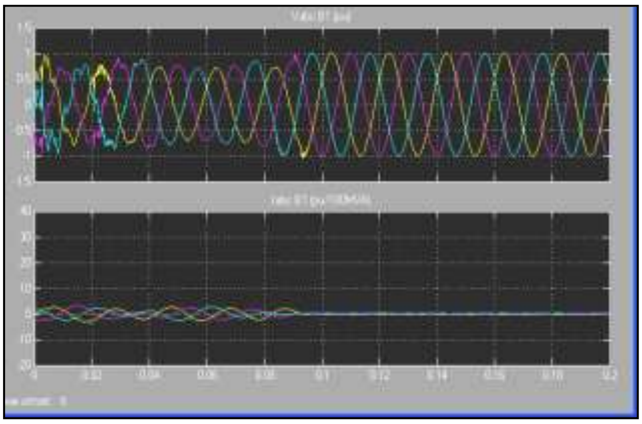

Fig. (7-e): Transient Response before Series Capacitor Compensation.

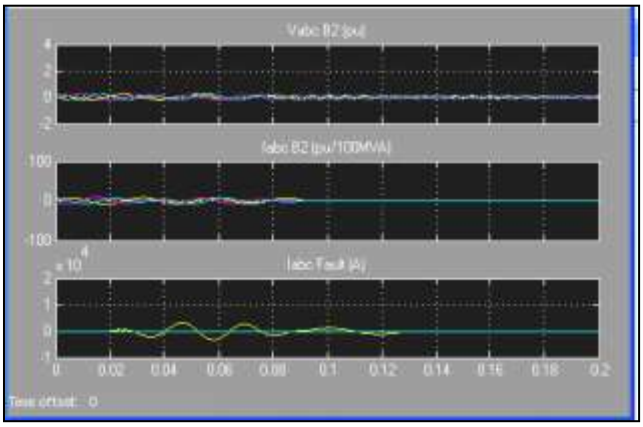

Fig. (7-f): Transient response after Series Capacitor Compensation.

3 - METHODS OF NEUTRAL GROUNDING

3. 1: Reactance Grounding For Open Loop Tap Changing Transformer

Reactance grounded used to limit the transient over voltage, zero sequence reactance greater than or equal ten of positive sequence reactance. This usually results in higher fault currents than resistance-grounded systems. One of the most common methods used for impedance earthing is the arc-suppression systems, which are similar in construction to transformers, but have a single winding on an iron core with air-gaps which immersed in oil. A neutral point resister is normally connecting in parallel with the neutral point reactor for over voltage protection in the neutral point, compensate for the effects of line capacitance and particularly to limit voltage rise on open circuit or light load. An arc–suppression coil is an iron - cored reactor mounted in the neutral to earth circuit and capable of being turned to resonate with earthing capacitance of the system when one line becomes earthed. The function of the arc suppression coil is to make arcing earth faults self - extinguishing and in the case of sustained faults to reduce the earth current to low value so that, the system can be kept in operation with one line earthed [20]. In the event of earth fault in the system shown in Fig. (8-a), which it illustrates transformer with arc - suppression coil with open loop tap changing transformer and Fig. (8-b) shows MATLAB simulation for three-phase open loop tap changing transformer (OLTC) regulating transformer (D/Yg) connection with eight ten positions, the neutral point resistor will be disconnected immediately and make it possible for the neutral point reactor to suppress the arc. The resistor is reconnected after an interval of (1.5 - 4) seconds; if the earth fault still remains the earth fault protection are permitted to operate**.** The inductance of the coil can be determined mathematically as follows:

The capacitive fault current is $I_{CF} = 3 * \frac{V_{phase}}{X_C}$ (8)

Also, fault current is, $I_F = \frac{V_{Phase}}{X_{Coil}}$ (9)

Where, X_{Coil} is the inductive reactance of the coil in ohm. At resonance condition,

$$I_F = I_{CF} \Rightarrow \frac{V_{phase}}{X_{Coil}} = \frac{3 * V_{phase}}{X_C} \text{ Or, } X_{Coil} = \frac{X_C}{3} \Rightarrow \omega L = \frac{1}{3\omega C} \quad (10)$$

$$\therefore L = \frac{1}{3 * \omega^2 C} \text{ in Henry} \quad (11)$$

This leads to some difficulty due to varying operational conditions for earthing capacitance of the network varies from time to time, however, the appropriate auto taps changing being used for each change in network conditions, this technique is suitable for Iraqi (11) k.V distribution substations [2]**.** From equations (9),(10) and (11) can be constructed Table (3), which illustrates variation of capacitive and inductive reactances with fault current and **Excel** program used to plot variation of tap changing inductance coil with fault current as shown in Fig. (8 - c).

Table (3): Variation of Capacitive and Inductive Reactances with Fault Current.

Fault Current I_F , Ampere	Capacitive Reactance XC, Ω	Inductive Reactance XL, Ω	Inductance mH	Resistance R, Ω
300	63.433	21.144	67.338	15.896
400	47.575	15.858	50.504	15.896
500	38.060	12.687	40.403	15.896
600	31.717	10.572	33.669	15.896
700	27.186	9.060	28.659	15.896
800	23.787	7.929	25.250	15.896
900	21.144	21.144	22.446	15.896
1000	19.030	6.343	20.20	15.896
1100	17.300	5.766	18.365	15.896
1200	15.858	5.286	16.834	15.896

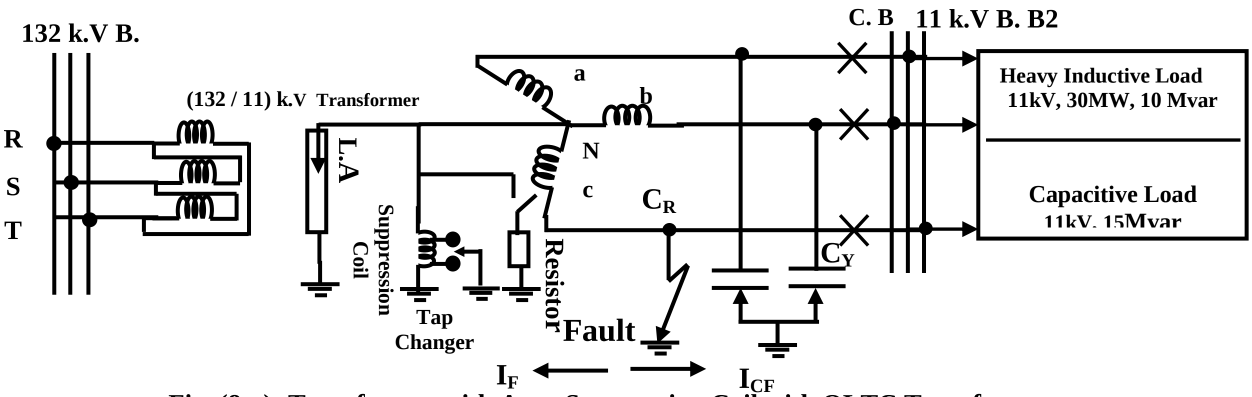

Fig. (8-a): Transformer with Arc - Suppression Coil with OLTC Transformer.

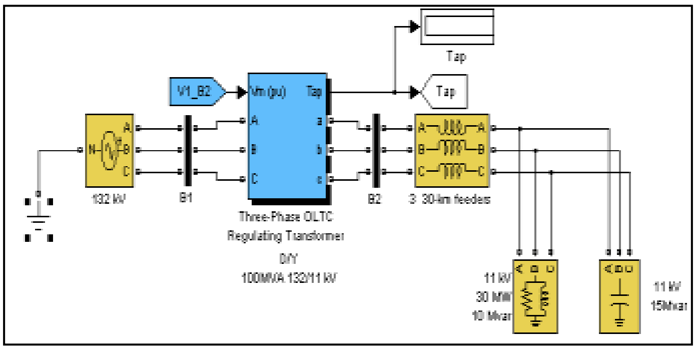

Fig. (8-b): MATLAB Simulation for Open Loop Tap Changing Transformer

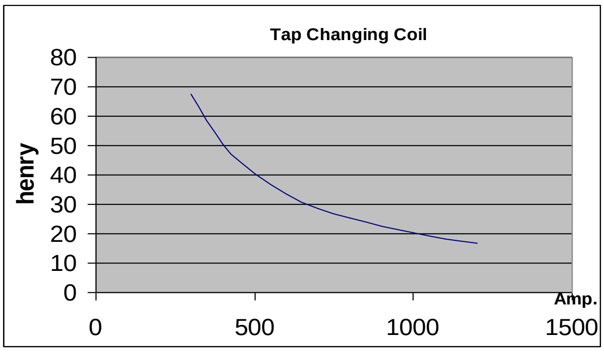

Fig. (8-c): Variation of Tap Changing Inductance of Coil with Fault Current.

3.2: Effective Grounding

A system can be said to be effectively grounded when all points on the system or specified portion, have the ratio of zero sequence reactance to positive sequence reactance is less than or equal three and the ratio of zero sequence resistance to positive sequence reactance is greater than one for any condition and for any amount of generator capacity**.** This method is used to control on earth fault current by opening and closing number of isolated neutrals; this in turn controlling the value of zero sequence reactance **[19].** If earth fault current is required to reduce its value, it's useful to open isolator earthing, consequently, increasing zero sequence reactance (X_0) and so increasing ratio of zero to positive sequence reactance, which is coming from the ratio between earth fault current to the three phase short circuit current, so mathematically:

$$I_{1\varphi} = \frac{3 * V_{Phase}}{x_1 + x_2 + x_0} \qquad (12)$$

And, $$I_{3\varphi} = \frac{V_{Phase}}{x_1}$$

(13)

If positive is equal to negative sequence reactance i.e., ($x_1 = x_2$). from equations (12) and (13)

gives: $$\frac{I_{1-\varphi}}{I_{3-\varphi}} = \frac{3 . x_1^2}{2 + \frac{x_0}{x_1}}$$

(14)

If, the zero sequence reactance equal positive sequence reactance I.e., $x_0 = x_1$

$\Rightarrow I_{1\text{-}\varphi} = I_{3\text{-}\varphi}$ Similarly, if $x_0 = 2 * x_1 \Rightarrow I_{1\text{-}\varphi} = 0.75 * I_{3\text{-}\varphi}$

Effectively grounded permits the use of lower rated (80) % lighting arresters and reduces fault current in comparison with solidly grounded circuits. The reactance limitations provide a fault-relaying current of at least (60) % of the three-phase short circuit value. The higher zero sequence reactance causes higher over voltages and; consequently, a higher demand on insulation level, this method is very suitable for Iraqi (132) k.V transmission network [2].

4 - HARMONIC SUPPRESSION AND PASSIVE FILTER

Parallel operation of generators have several advantages used for maintenance, continuity service adequacy and cyclic testing, but when the voltage wave for one of the generators is non-sinusoidal, the third harmonic voltage may cause third harmonic current to flow from the generator line terminals through the system and return by a way of comparatively low zero sequence reactance path of other generators to its neutral terminals **[20] and [21].** It is necessary to reduce voltage and current harmonics to a safe value; this is done by the use of harmonic suppression coil in the neutral earthing connection of the generator. It comprises of an iron cored reactor and presents a high impedance path to flow of harmonic currents and a low impedance path to flow of fault currents. This criterion is obtained by designing a reactor, so that its core becomes saturated at very low system frequency fault currents. Continuous operation with excessive harmonic current can lead to increase voltage stress, rise temperature and can shorten the life time of components; typically, a (10) % increase in voltage stress will result a (7 %) increase in temperature, which is reducing the life expectancy to (30 %) [22]. In order to prevent a high voltage build up it is necessary to connect lightning arrester of ($1\,\Omega$) between the generator neutral point and earth to avoid surge in voltage .automatic synchronizing equipment (ASE) device is needed to synchronize voltages with (5) degree error of phase shift, frequencies with (10) % difference, symmetrical phase angles between two sided of connections and start up for circuit breakers. If all the generators have their (e.m.fs) out of phase, this means that the system is swing; consequently, un-synchronizing current flows. Voltage transformer acts as a very high reactance earthing device and does not assist in mitigating the over voltage conditions. Fig. (8-a), which represents the use of harmonic suppressors in neutral earthing circuits of two generators and transformers connected in parallel for the same Bus - Bar of (11) kV. Fourier s theorem provides the mathematical tool for resolving a periodic waveform of virtually any shape into a sum of harmonic components. In general the instantaneous power $p = \upsilon . i$, so

$$P_{\text{avarage}} = \sum_{m=0}^{\infty} v_m I_m \cos\phi_m$$

So, $P_{avarage} = V_o I_o + V_1 I_1 \cos\varphi_1 + V_2 I_2 \cos\varphi_2 + ...$ (15)

There are two conditions to follow harmonic current, which are resultant harmonic voltages and a path for harmonic currents. Due to third harmonic currents in electrical networks result overheating of transformer windings & load and increased iron loss in transformers. Due to third- harmonic voltages result increased transformer insulation stresses ,electrostatic charging of adjacent lines and telephone cables and possible resonance at third harmonic frequency of transformer windings and line capacitance. Passive filters for harmonic reduction provide low impedance paths for the current harmonics. The current harmonics flow into the shunt passive filters instead of back to the supply. The passive filter consists of series L C filters tuned for fifth harmonic [23]. The performance of a passive filter is strongly dependent on the system impedance at the harmonic frequencies while the system impedance depends on the network configuration and the loads. Therefore, design of passive filters involves thorough system analysis in order to obtain adequate filtering performance of the filter. The overall conclusion prevailed showed that the harmonics flow is strongly connected to the nonlinear load position and definitely on the harmonic order Fig. (8 -a) shows earthing of generators using harmonic suppression method. Three phase harmonic filters are shunt elements that are used in power systems for decreasing voltage distortion and for power factor correction. Non-linear elements such as power electronic converters generate harmonic currents or harmonic voltages, which are injected into power system. The resulting distorted currents flowing through system impedance produce harmonic voltage distortion. Harmonic filters reduce distortion by diverting harmonic currents in low impedance paths. Harmonic filters are designed to be capacitive at fundamental frequency for n order to achieve acceptable distortion, several banks of filters of different types are usually connected in parallel. The most commonly used filter types are Band-pass filters, which are used to filter lowest order harmonics such as (5th, 7th, 11th, 13th, etc). Band-pass filters can be tuned at a single frequency (single-tuned filter) or at two frequencies (double-tuned filter).High-pass filters, which are used to filter high order harmonics and cover a wide range of frequencies. A special type of high-pass filter is C- type high-pass filter, used to provide reactive power and avoid parallel resonances. It allows filtering low order harmonics (such as 3rd), while keeping zero losses at fundamental frequency. The resistance, inductance, and capacitance values are determined from the filter type and from the following parameters: reactive power at nominal voltage, tuning frequencies and quality factor. The quality factor is a measure of the sharpness of the tuning frequency; it is determined by the resistance value. The double tuned filter performs the same function as two single-tuned filters although it has certain advantages: its losses are much lower and the impedance magnitude at the frequency of the parallel resonance that arises between the two tuning frequencies is lower. The double-tuned filter consists of a series LC circuit and a parallel RLC circuit. If f_1 and f_2 are the two tuning frequencies, both the series circuit and the parallel circuit are tuned to approximately the mean geometric frequency: $f_m = \sqrt{\frac{f_1}{f2}}$. The C- type high-pass filter is a variation of the high-pass filter, where the inductance L is replaced with a series LC circuit tuned at the fundamental frequency. At fundamental frequency, the resistance is, therefore, bypassed by the resonant LC circuit and losses are null. Fig. (9-b) illustrates MATLAB simulation for harmonic filters in power system, Fig. (9-c) shows filters impedance versus harmonic frequency and Figs. (9-d) & (9-e) illustrate transient response for voltage supply and current before and after insertion harmonic filters. The proposed model is rather simplified and also has excellent behavior and good stability.

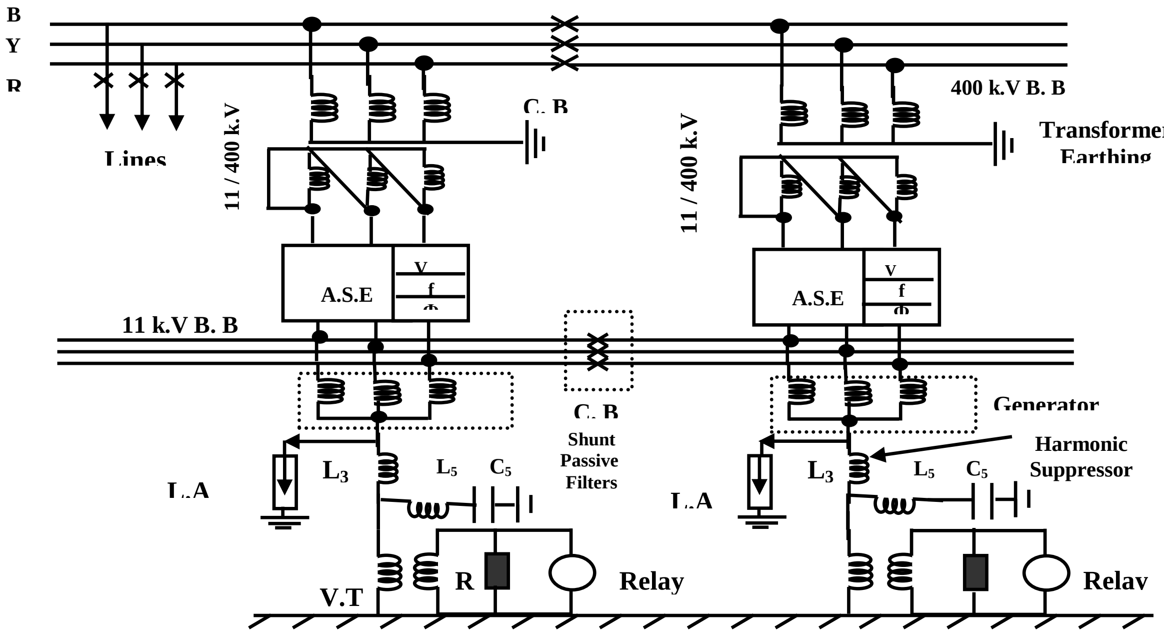

Fig. (8 -a): Earthing of Generators Using Harmonic Suppression Method.

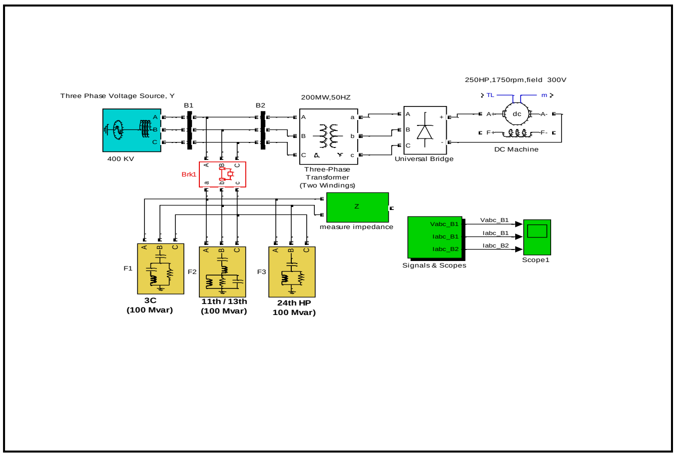

Fig. (8 -b): MATLAB Simulation for Harmonic Filters in Power System

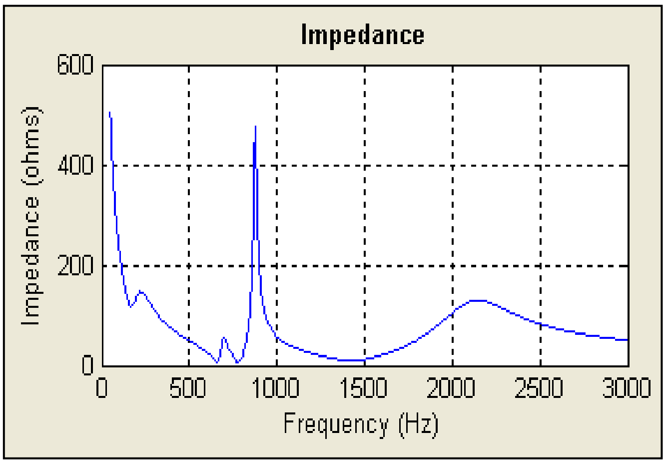

Fig. (8 -c): Filters Impedance Versus Harmonic Frequency

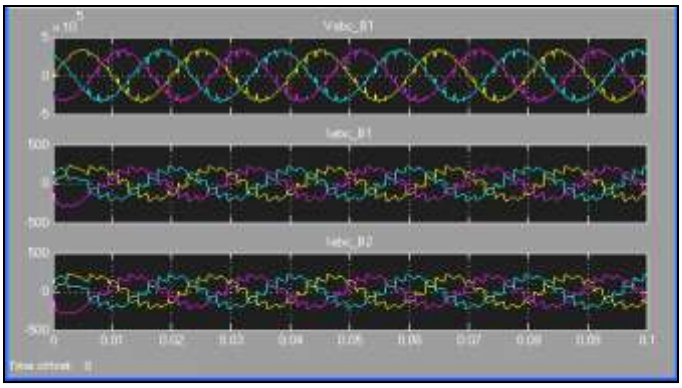

Fig. (8-d): Transient Response for Supply Voltage and Current before Insertion Harmonic Filters.

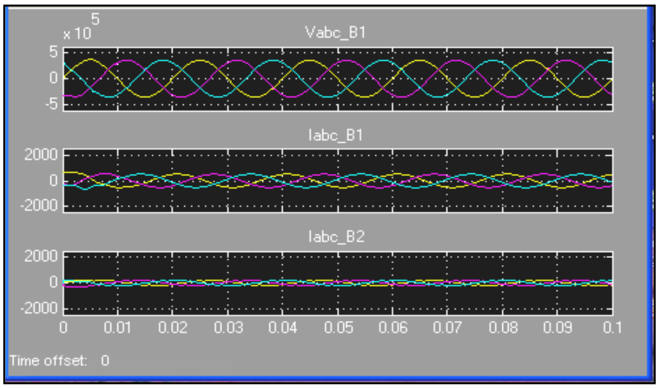

Fig. (8-e): Transient Response for Supply Voltage and Current after Insertion Harmonic Filters.

5 – CONCLUSIONS

1. Stand by redundancy principle is more appropriate than parallel redundant, in which the failure probability of a system is less, compared with parallel redundant system.

2. The choice of particular bus - bar arrangement depends on various factors, such as system voltage, position of the substation in the system, flexibility, good performance and cost of supply.

3. Economic dispatch orders the minute to minute loading of the connected generating plant so that the cost of generation is a minimum with respect to the satisfaction of the security, quality and other engineering constraints such as bus- bar voltage and frequency variations.

4. The best rate of dissipation is affected by good choice of the size of dynamic brake. The accurate timing of insertion and removal of the dynamic brake leads to better damping of swings caused by disturbance.

5. In power thyristor switched capacitor (TSC) the change in number of units in conduction state can make every half cycle.

6. When earth fault current is required to reduce and limit its value, it is useful to open the isolator earthing; consequently, increasing zero sequence reactance and so increasing ratio of zero to positive sequence reactance.

7. Continuous operation with excessive harmonic current can lead to increase voltage stress, rise temperature and can shorten the life time of components; typically, a 10 % increase in voltage stress will result a seven percent increase in temperature.

8. The proposed models are rather simplified and, also has excellent behavior and good stability. The high accuracy, fast simulations and flexible levels of detail make this improvement more valuable and helpful for transient simulations and control design.

9. From power system calculation that adding the shunt capacitors to control the voltage level and reduce the amount of power loss in transmission lines by (50) % ,which represents the difference before and after shunt capacitor compensations, while the power losses in Iraqi electrical networks is (10) % of total electrical power generated.

10. Three phase harmonic filters are shunt elements that are used in power systems for decreasing voltage distortion and for power factor correction. The C- type high-pass filter used to provide reactive power and avoid parallel resonances.

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6 - REFRENCES

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