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Simulation based Analysis of Single Unit and Parallel Connected Three Phase AC Generators in QUEST Campus Larkana

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Abstract:
Recently power crises are increasing day by day in Pakistan due to a shortage of energy resources. The financial position of Pakistan is too weak and is not in a position to install new power projects for the production of electrical power to meet the demand as per requirement. Every consumer is trying to install the power-producing devices to meet the demand in order to run their institutional laboratories, offices, commercial plants, and industrial machines. Electricity for resident people of villages of Pakistan is not sufficient to run their home appliances and mostly solar systems has installed to meet the requirement in day time but in night time energy storage system is required, so cost will be increased and less illumination is received at night time. The generator is also one of the power producer devices to meet the consumers' demand to supply the electrical power to the load in absence of failure of power supply from utility companies. A single large unit is very expensive to run the small loads and consumes large amounts of fuel, so the parallel connection of two small generators is very beneficial to meet the demand as per requirement, resulting in cost savings, and less fuel consumption. QUEST Campus Larkana has installed two 50KVA generators in parallel to supply the required power to the load in absence of a power supply to run their offices, workshops and laboratories, this minimizes the cost, and increases the reliability of the system. The MATLAB simulation model is developed to analyze the performance of the single unit generator and parallel connected generators.

Keywords: *AC Generators, Power Supply*

1. Introduction

Recently power crises are increasing day by day in Pakistan due to a shortage of energy resources and poor financial position to install new power projects for the production of electrical power to meet the demand as per requirement [1]. Educational institutions, hospitals, laboratories, industries, residential, and commercial consumers are facing power crises and very difficult to manage the workstations in absence of electrical power [2]. As shown in figure 01 the power demand in Pakistan. Every consumer of electricity is trying to maintain his power system in boundary wall through addition of standby system to provide facilities to students and officers in educational institutes, patients and their staff in hospitals, and increase in revenue of production industries [3, 4]. Every country wants to run their industrial sector properly for development but due to the power quality problems and shortage of power, the required output is badly affected [5].

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Power quality can be improved by installing the devices [6, 7] but the shortage of power is a serious problem for proper manufacturing in the industrial sector [1]. Electricity for resident people of villages of Pakistan is not sufficient to run their home appliances and mostly solar systems have been installed to meet the requirement during day time but at night time energy storage system is required, so the cost will be increased and less illumination is received at night time [4, 8]. The shortfall of electrical power is increasing day by day in Pakistan, cities are facing 6 to 8 hours of daily load shedding, villages are more than 12 hours in a day, and some of the villages are without electricity [2]. Hospitals, medical laboratories, institutions, industries, and large commercial offices have large loads and they have also required stand-by systems to run their loads at day and night time [9]. Electrical generator is one of the standby systems to meet the consumers' demand [10] which convert mechanical energy into electrical energy and available in small and large ratings to meet the consumers' requirement day and night.

Quaid-e-Awam University of Engineering and Technology campus Larkano was established in 2010 which is a constituent campus of the QUEST Nawabshah. There are four Engineering departments and initially, one batch was admitted in 2010 and installed 50KVA generator to meet the power demand in case of failure. After increasing the laboratories, staff offices, and induction of more student batches one more 50KVA generator was added in parallel to meet the demand. In case of low power requirement, only single unit is running and the other is remained off, this will give saving in consumption of fuel [11], so two small rating generators are beneficial instead of a single unit of large capacity which consumes large amount of fuel, and large in size. MATLAB simulation software is used to develop the model of a parallel connected generator to analyze the performance under small and large loads. Different power companies are intensively taking part in investments to enhance wind generation and overcome the shortage of electrical power in Pakistan [12], [13]. The utilization of oil and coal since 2015 has increased so we cannot more rely on oil and coal due to costly, which will directly hit the economy of the country [14]. Natural gas is available in Pakistan but the Oil and Gas Company of Pakistan (OGDCL) has declared that the natural gas will be reduced from 2025 to 2030 so we cannot rely on natural gas for the installation of more power plants in Pakistan in order to meet the power demand [15]. Figure 1 shows the supply-demand gap in Pakistan from 2002-2030.

Section 2 AC Generator

Section 3 Parallel Connection of generators

Section 4 Parallel connected generators in QUEST Campus Larkana

Section 5 Simulation Results and discussions

Section 6 Conclusions

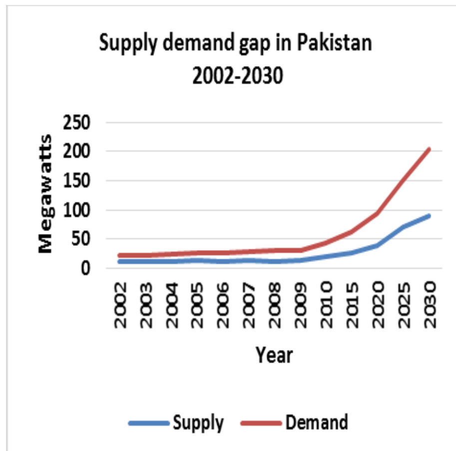

Fig. 1. Supply Demand Gap in Pakistan 2002-2030

2. AC Generator

The Generator is a device that converts mechanical energy into electrical energy and works on Faradays law of electromagnetic induction [16]. It consists of a coil of wire which rotates in a magnetic field. According to faradays law, the emf is induced when the current-carrying conductor is placed in a magnetic field [17], the simple AC generator is shown in figure 2 [18]. The direction of induced emf is calculated through Flemings right-hand rule, the process is repeated for each cycle [19] as shown in figure 3 [20]. It has been seen that at point A there is 00; no emf is generated because coil movement and direction of a magnetic field are in parallel with each other. At point B there is 900; maximum emf is generated because coil movement is at 900 to a magnetic field. At point C there is 1800; no emf is generated because coil movement and direction of a magnetic field are in parallel with each other. At point D there is 2700; maximum emf is generated because the coil movement is at 2700 to the magnetic field but opposite to point B. Finally, at point A there is 3600; no emf is generated because coil movement and direction of a magnetic field are in parallel with each other and the coil completed the rotation [3].

Assume that the coil shape is rectangular and has N no of turns with angular velocity ω and rotates in uniform magnetic field B and coil at any time is t then the angle between a magnetic field and coil time is given in equation (01) and magnetic field perpendicular to the plane of coil is given in equation (02) .

$$\theta = \omega t(01)$$

$$\varphi = B\cos\omega t(02)$$

When a magnetic field is linked with coil of N turns then

$$\varphi = B\cos\omega tA(03)$$

Where A is area of coil, induced emf in the coil according to faradays law

$$\varepsilon = -d\emptyset/dt$$
$$\varepsilon = -d(NBA\ \cos\omega t/dt$$
$$\varepsilon = NBA\omega \mid \sin\omega t(04)$$

When coil is rotate with 900 then the value of sin is 1 then equation (04) becomes

$$\varepsilon_0 = NB_mA\omega = NB_mA\ 2\pi(05)$$

Where B_m denotes the maximum flux density and A is the cross sectional area and f is the frequency of coil rotation, now add equation (05) in equation (04) then we get

$$\varepsilon = \varepsilon_0 sin\omega(06)$$

The induce current is given in equation (07)

$$I = {}^{\varepsilon_0}/_{R} = \varepsilon_0 Sin\omega(07)$$

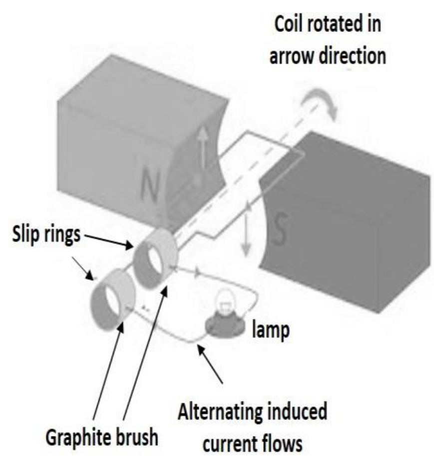

Fig. 2. Simple AC Generator

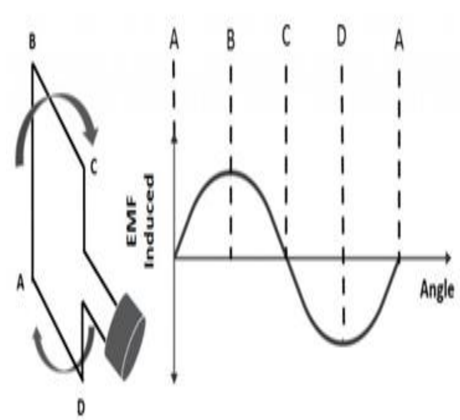

Fig. 3. Different Positions of a Coil

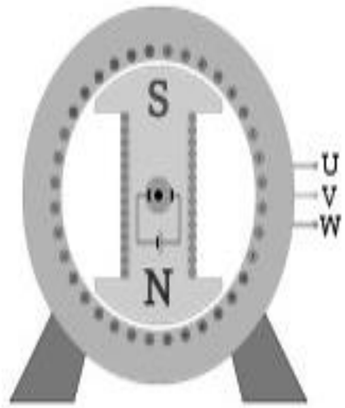

Fig 4 (a)

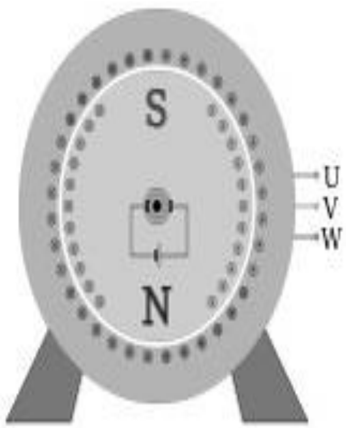

Fig 4(b)

Fig. 4. (a) Salient Pole Rotor, (b) Non-salient Pole Rotor

AC generator is a very essential device that meets the requirement of electrical power in the shape of generation. In AC generators the slip rings are employed to produce the alternating current and are available in small and large capacities and mostly applied to the power plant for the generation of electrical power and in commercial and industrial sectors to meet the energy gap [21]. The main parts of the generator are the stator and rotor. The stator is a stationary part fixed an armature winding that carries the current for the load, it consists of a frame, stator core, and armature winding [22]. The rotor is the rotating part of the generator, it consists of magnetic field winding and a dc supply is used to magnetize the magnetic poles. Salient and non-salient type rotors as shown in figures 4(a) and 4(b) are used depending on the point of application [23].

3. Parallel Connections of AC Generators

When a load is increased beyond the capacity of a single unit of AC generator, another generator is connected in parallel to meet the required demand [11]. The single unit of large rating is heavy, large in size, and more costly to replace a single unit of small capacity with a large one and in case of fault the whole unit will be replaced with another one for maintenance, resulting in revenue loss, large labor charges and also disturb the reliability of power to run the offices, laboratories, and industries [24]. It is a dire need to connect a small rating of two AC generators in parallel to meet the required demand. If one unit of generator is faulty then we can run our major machines, laboratories, and office equipment till the availability of another unit safely [25]. Two small units of parallel connected generators give result in small size, less weight, easy maintenance, and reduced revenue loss [26]. The parallel connection is possible when the terminal voltage of the two generators must be the same otherwise high current will flow between the two machines, resulting in damaging the equipment or generator [27]. The frequency of both generators must be the same otherwise the low-frequency generator takes more loads and results in the overloading of the generator [28]. The output voltage must be the same in phase otherwise large output voltage is developed in phase [29].

4. Parallel Connected AC Generators in QUEST Campus Larkana

QUEST Campus Larkana was established in 2010. There are four Engineering departments and initially, one batch was admitted in 2010 and installed a 50KVA generator to meet the power demand in case of failure. After increasing the laboratories, staff offices, and induction of more student batches one more 50KVA generator was added in parallel to meet the demand and run the load of 400Amperes.

Fig. 5. Parallel Connected Generators at QUEST Campus Larkana

In case of low power requirement, only a single unit is running, and the other is remained off, this will give saving in consumption of fuel [11], so two small rating generators are beneficial instead of a single unit of large capacity which consumes a large amount of fuel, and large in size. Figures 5 and 6 show the AC generators available at campus Larkana.

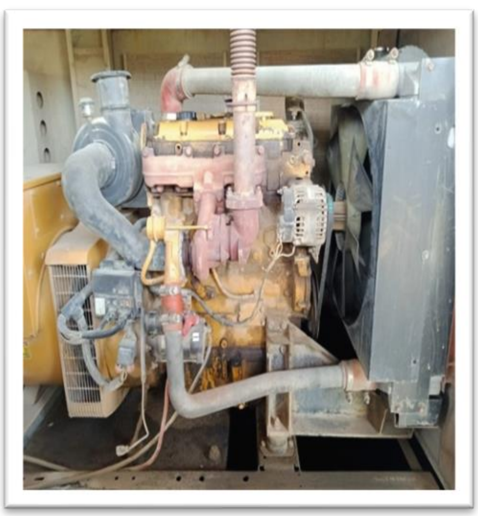

Fig. 6. Inner look of 50KVA AC Generator

5. Simulation Results and Discussion

The simulation model is developed in MATLAB software and analyzes the performance of the AC generator when operating alone and in parallel under normal and overload conditions. Figure 7 shows the Simulation model of parallel connected generators and Table 1 shows the parameters of generators.

TABLE I. PARAMETRS OF AC GENERATORS

S.No	Generator Parameters	Value
1	Capacity of AC Generator	50 KVA
2	Output voltage per phase	220 volts
3	Frequency	50 Hz
4	Inertia	$3.7e^3$
5	Pair of poles	2 Nos
6	Internal Resistance of AC generator	0.0001 Ohm
7	Internal Inductance of AC Generator	0.05 Henry
8	DC Machine Field type	Wound
9	Armature Resistance of DC machine	24 Ohm
10	Field Resistance of DC machine	618 Ohm
11	Field Inductance of DC machine	0.05 Henry
12	Field Armature mutual inductance of DC machine	1.8 Henry
13	Initial Field Current of DC machine	0.3 Ampere

14	DC voltage source	169 Volts
14	Mechanical input	Speed
15	Sampling Time	-1

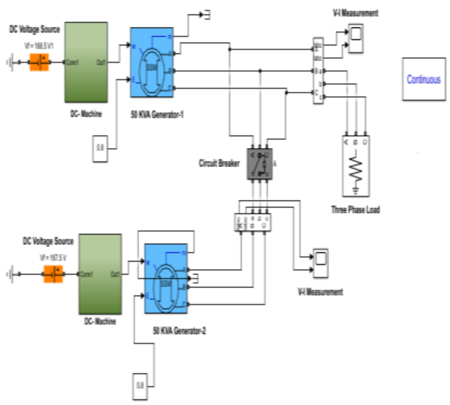

Fig. 7. Simulation Model of Parallel Connected Two 50KVA AC Generator

5.1. Single Unit Generator Opearting alone (At 150 Ampere Load)

In the initial stage, a load of QUEST campus Larkana was 195 Amperes and one single unit was sufficient to meet the supply gap. It has been seen in this simulation result from the single unit of generator produces the 220Volts single phase without any oscillations and meets the requirement satisfactorily. Figure 8 shows the simulation result of the generator under normal load conditions.

5.2. Single Unit Generator Opearting alone under variation of input and reference parameters (At 210 Ampere Load)

When the load of the campus was increased beyond the capacity of a single generator, so it has seen in this simulation result that the output voltage of a single unit of the generator is reduced from 220Volts to 170Volts and not meets the requirement satisfactorily and after some time heat will be generated and shut down. Figure 9 shows the simulation result of the generator under variation of input and reference parameters.

5.3. Single Unit Generator Opearting alone under variation of input and reference parameters (At 230 Ampere Load)

When the load of the campus was increased beyond the capacity of a single generator i.e. up to 230Amperes, so it has seen in this simulation result that the output voltage of a single unit of the generator is reduced from 220Volts to 135Volts and not meet the requirement satisfactorily and after some time heat will be generated and shut down. Figure 10 shows the simulation result of the generator under variation of input and reference parameters.

5.4. Two Generator Opearting Parallel (At 320 Ampere Load)

When the load was increased and to run the offices, labs, classes, and other loads satisfactorily, another generator of 50KVA was added to the first generator in parallel. It has been seen in this simulation result that the parallel operation of two generators share the load and produces the 220Volts single phase and meets the requirement satisfactorily. Figure 11 shows the simulation result of the parallel operation of two generators.

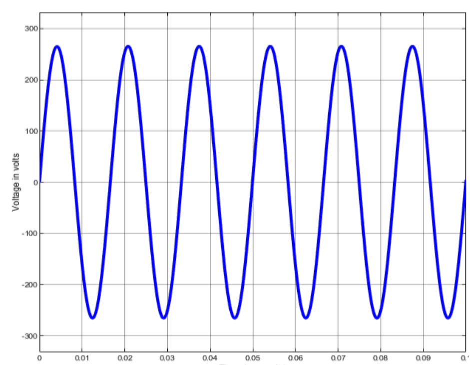

Fig. 8. Single Unit Operation of Generator Under Normal Input and Reference Parameters

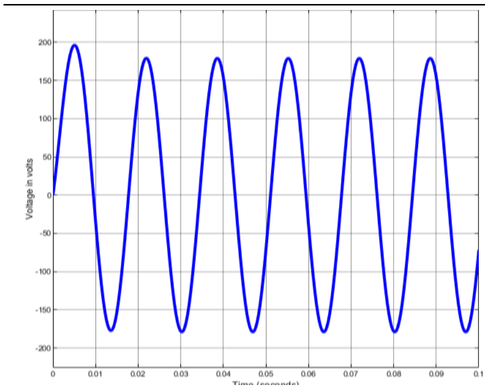

Fig. 9. Single Unit Operation of Generator Under Variation of Input and Reference Parameters

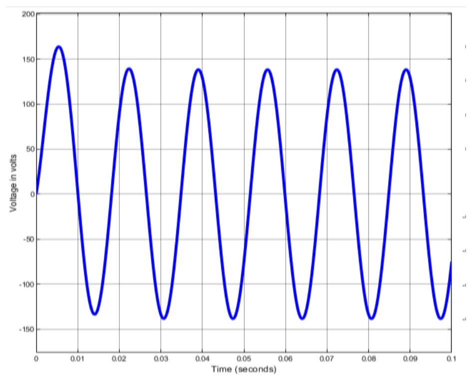

Fig. 10. Single Unit Operation of Generator Under Normal Input and Reference Parameters

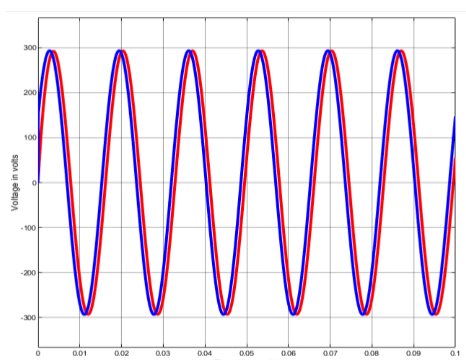

Fig. 11. Parallel Operation of Two AC Generators

5.5. Discussion

It has been seen from the literature that the power crises are increasing day by day in Pakistan due to that our industrial sectors, public sector, and commercial sectors are facing very difficulty in keeping the reliable operation of their equipment. The Solar system is more costly and difficult to get energy at the night time. So an AC generator is the best option to meet the energy gap in day and night time. It has been seen from simulation results that the performance of a single-unit generator is not satisfactory under overload conditions and consumers received less voltage for utilization and the generator overheated and shut down. To eliminate this problem another generator of the same rating is connected in parallel to get the satisfactory performance of generators under overload conditions. Table 2 shows the simulation results of the operation of AC generators operating alone and in parallel.

TABLE II. SIMULATION RESULTS OF AC GENERATORS OPERATING IN PARALLEL AND ALONE

Load	**Single Unit Generator**	**Parallel Connected Generators**
150 Ampere	220 Volts per phase	Operation not started
210 Ampere	170 Volts per phase	Operation not started
230 Ampere	135 Volts per phase	Operation not started
320 Ampere	----	220 Volts per phase

6. Conclusion

This research study is carried out in the Quaid-e-Awam University of Engineering and Technology Nawabshah Campus Larkana to analyze the performance of the single unit generator and parallel connection of two generators to meet the energy demand in case of failure of the power supply. In Pakistan, the energy demand is increasing day by day, and currently facing a shortage of energy due to that 6-8 hours load shedding is carried out in cities and 12-14 hours in villages. Hospitals, Laboratories, Industries, Commercial loads, and Universities are very responsive places so the availability of electrical power is essential to carry out the work properly. For the continuity of power supply stand-by system is necessary in shape of AC generators because the solar system will be affected in the rainy season, cloudy conditions, and nighttime. The two generators of 50KVA are available in QUEST Campus Larkana to meet the required energy gap. It has been seen from the simulation results that when a load is increased beyond the capacity of a single unit of the generator then the output voltage is decreased and the generator is overheated after some time generator is shut down, so it is necessary to add another generator in parallel with a single one to share the load. The output voltage remains within the limit and the problem of overheating and shutdown is eliminated. Singe large unit of generator is costly and heavy and also a problem in maintenance, so it is concluded that the two generators of small capacity are installed, resulting in easy maintenance, reduce cost, and small in size to meet the energy demand in Industries, Hospitals, Universities, and laboratories.

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