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Optimization of Power Plant for Telecom Sector Based on Embedded System

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ABSTRACT

Modern Telecom Sector is eventually facing exceptionally tough challenges because of continuous and unexpected increase in power density requirement for the communicating machinery and equipment. To fulfil the power requirements for the equipment, a significant architecture and an optimal technique must be introduced. In this paper, a microcontroller-based optimization use of power-density has been carried out. Meeting above requirements, various equipment and electronic devices are employed. We have designed a microcontroller-based system via PROTEUS Virtual System Modeling to acquire efficient and effective results. The main focus of our work is to supply the power to Telecom equipment in meantime. The power is feeding on batteries and DG (Diesel Generator) set, depending on the condition of the power requirements. The changeover operations are performed by different relays, which are dully programmed via a microcontroller in Keil software. The power capacity of Telecom ((Telecommunication) equipment is ranged from 39-48 Volts DC. The rectification process is done by switch mode rectifiers instead of linear rectifiers. Because the switch-mode rectifier technology has brought fabulous improvements in power density as compared to linear rectifiers. This is done via simulation of the smart switch in PROTEUS software. The outcomes of the proposed system are cost-effective in terms of fuel consumption of DG.

Key Words: Telecom Equipment, Changeover, Switch, Power Monitoring, Uninterruptible Power, Microcontroller

1. INTRODUCTION

At present, Pakistan is facing severe crises regarding power energy. Because, there is a big margin between demand and supply, that's why an alarming situation has been created. Due to which shortfall of electric power is increasing day by day, so it is impossible to avoid power shortages. Because of this, not only the economic growth and commercial Sector of our country is badly affected, but Telecom sector is one of the major victim. So, an alternate technique, a standby power system is introduced to overcome this issue as given in [1-5].

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Many researchers have worked for the optimization [2-6], energy conversion [1-2,7], security and safety [8] and management [9] of power and energy for Telecom sector by incorporating different techniques and methods like electromechanical relays [3,8], function generator [10] and embedded systems [9-12]. The function generator is important for communication, radar, electronic equipment, and other sector as well for generating different frequency ranges for the system on the principal of phase control [10].

In [1], authors have proposed a simple energy conversion system based on the fuel cell to supply energy for Telecom equipment. Their system has curtailed significant operation and maintenance cost of Telecom machinery and equipment. In addition, they also presented a closed loop and a controller with a genetic algorithm to perform voltage regulation at the base transceiver station for the power conditioning. That system was simulated in MATLAB/Simulink software. In [2], authors have also worked on energy conversion and voltage regulation by proposing multicell converter-based approach.

In [3], authors have proposed some effective approaches like cost-effective and implementation of change-overs for the optimization of the system. By employing these approaches, the system will meet at high ranks. The cost-effective approach can only be made possible by applying different techniques of implementing changeovers to the system, like manually operated changeover system and automatic changeover system. These changeover systems can be operated by automatic transfer switch or electromechanical relays. EMR (Electromechanical Relays) are also used for the security and safety of electrical system by measuring the electrical parameters such as, current, voltage and frequency. Then the measured values are sent at remote stations by GSM (Global System for Mobile Communication) network [8]. The relays will be activated automatically whenever above electrical parameters go beyond the thresholds. A circuit breaker is operated with that relay, which turns-off the whole circuitry.

Another mechanism for shutting down the whole unit is via radio frequency [11]. This technique is very useful in case of a rapid increase in current, voltage and temperature of the system. So far, the system is predicted from rapid rise of electrical and environmental parameters. For continuous measurement of electrical parameters, viz. voltage, current, frequency generation, the speed of the turbine, etc., embedded systems are now widely used in Telecom Sector [12]. For the provision of adequate energy to the system from storage devices such as batteries and super-capacitors, energy conversion methods have been introduced in [7]. In this system, the main intention is to provide a prescribed active and reactive energy to the system. Their system is very useful for avoiding the high charge and overcharge states of the batteries, with an aid of a dedicated control system. In [9], a microcontroller-based management scheme has been presented to monitor the low voltages for battery operated systems. The designed system has features of optimized usage of energy resources, reduction of cent percent operation of DG sets to curtail maintenance cost, reduction of fuel expenditures, and elimination of a human interference.

Telecom power plants conventionally consist of grid, DGs, backup power system, rectifiers and switches [21]. In [22-23], a microgrid based Telecom power plant are designed to provide uninterrupted power to Telecom equipment. Mostly, batteries and super capacitors are used as a backup power system. For the provision of a continuous power supply, UPS (Uninterruptible Power Supply) are also incorporated [14-15].

Our objectives are as under:

(i) Ensure smooth/uninterrupted functioning of Telecom services

(ii) To reduce the cent percent operation of DG to curtail the fuel expenditure.

(iii) Optimal utilization of battery banks within safe limits.

(iv) To reduce the human interferences by proposing a smart switch.

The paper organization is: section II covers the problem statement, quoted from early presented work regarding changeover system and techniques. Section III is all about Telecom power plant, in which power requirements and considerations are described. Section IV illustrates the complete system design, software and operation scenario. Experimental results are mentioned in section V. Conclusion is given in section VI.

2. PROBLEM STATEMENT

Standby power system is the prime requirement for the industrial, comsmercial, Telecom and domestic electrical power systems. The load, which is directly connected to the grid power must be backed up with any source which is capable to run that electrical power system continuously. In addition, there must be a system which can transfer the electrical load without any trouble; this can be done by monitoring power plants as suggested in [13]. For this, smart switches are widely used to switch the load from grid power to the backup power system for the smooth operations and self-protection [18]. These smart switches have features to control the system and effortless operation without the interference of human beings. There is a lot of work has been done in the field of Telecom power plants, automatic changeover switch boxes, power supply by generators, etc. by various scientists and engineers. The automatic changeovers are implemented in various industrial and commercial sectors to ensure the continuous supply of power depends on the both on-site generator and public supply. Due to a rapid growth of electrical systems and its complexity, it is crucial to increase the stability and reliability of the system. Since many years, a lot of work has been done, novel approaches have been introduced and implemented [3]. Out of some are described below.

2.1 Manual Changeover Switch Box

The main task of manual changeover switch box is to isolate the sources between public supply and generator [3,19]. The changeover is operated manually by a human when the power becomes fail and the same is restored manually when power is restored. Performing this task, there is a substantial risk of electrical shocks and spars, as well as a lot of noise, are also present. Beside this, other limitations of manual changeover could be highly laborious to operate, high operation and maintenance cost, chances of damage and the time consumption as well.

2.2 Electromechanical Relays Based Automatic Changeover System

A relay; it is a type of a switch that works on the principle of electromagnetic and activated whenever its inputs are varied, and desired output will be achieved. There are two types of relays used commonly, the normally open switch and normally closed switch [3,20]. Nowadays, the EMRs are used in the electronic circuitry with many other devices to perform automatic changeover operation. An automatic system based on the electromechanical relay is shown in Fig. 1. In Fig. 1, EMR is used to oppose the return flow of AC (Alternating Current) signals into the electronically controlled devices.

The automated changeover switching system is superior to manual changeover switching system, because, it is faster, reliable, automatic, but despite various advantages, there are some hurdles yet, that are described below [3]:

(i) Tear and wear

(ii) Switching relays have a lot of noise

(iii) Archiving that can let off fire

(iv) A lot of components and devices, this may prone system to fail

2.3 Changeover with Automatic Transfer Switch

An automatic transfer switch is also used in the changeover system [20-21], this observes the AC voltage failure conditions coming from a power distribution company like HESCO (Hyderabad Electric Supply Company) in Pakistan. The predetermined conditions are set normally when the power failure occurs from

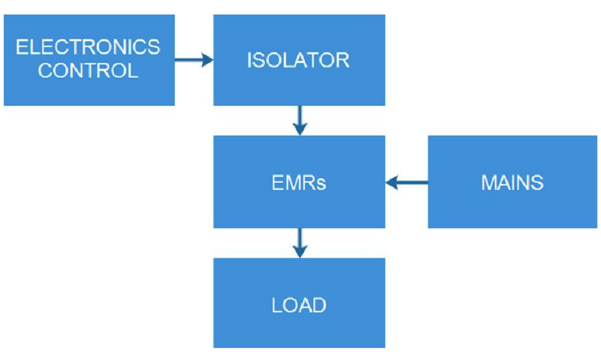

FIG. 1. BLOCK DIAGRAM OF AN AUTOMATED SYSTEM WITH RELAYS [1]

Distribution Company (i.e. main supply), then a standby system (generator) will be turned into the active state. Meanwhile, the load will be toggled to standby system (generator) from the main supply. Whenever main power supply is restored, the load will be switched back automatically.

3. TELECOM POWER PLANT

The convergence of ICT (Information and Communication Technologies) equipment and networks have furnished the basic need of energy and power. Today, designers and vendors of Telecom sector have facilitated a lot to the official user and clients about the power requirements as well as to configure the equipment to meet the wish for they are expecting, for example; reliability, stability and very important requirement of economic challenge. Usually, the Telecom equipment requires an input power of -48VDC (Voltage Direct Current) [4,17]. These types of power system have multiple numbers of redundant rectifiers; these rectifiers are here to convert 220/240 VAC (Voltage Alternating Current) input power to -48 VDC output power [21-23]. From this power, battery banks are also charged, mostly lead-acid batteries are used as the battery bank. Critical load equipment is also powered by UPS source [15]. UPS are used to derive the required -48 VDC from the power plant.

In the event of AC power failures or rectifier failure, essential equipment should be supported by standby battery for ample time. Sometimes, during sustained power failures, plant personnel use a DG to supply AC power. Standby batteries may have a support time range starts from at least one hour to 8 hours [16,21]. Traditional IT (Information Technology) equipment is manufactured so that they require input power as AC source with single phase. Generally, the available configurations are starting from 120, 220, or 240V with 60Hz (Hertz) frequency, whereas 220-240V single phase AC with 50Hz frequency may also be countered with [14]. A generic architecture of power supply to Telecom equipment is depicted in Fig. 2.

3.1 Power Requirements and Consideration

While selecting a power system, the configuration of its input power supplies of the fan-outs, to be considered the most important thing. There are some other key factors require attention, such as; operating efficiency, size, O&M (Operation and Maintenance) costs [14]. Nearly all the ITequipment require DC power. Henceforth, Telecom equipment also requires DC power. The Telecom equipment requires an input power of -48VDC. AC power is converted into 48VDC by DC power systems by using multiple parallel rectifiers, e.g. a 4000A rectifier system is usually built up by using up to 21 as well as the expectation of further rectifier modules of 220A. The value of MTBF (Mean Time Between Failures) of such conversion devices (i.e. rectifiers) is in the range of 100,000 and 200,000 hours [14]. It is observed that too many parallel rectifiers' applications increase conversion equipment failure. According to AC power engineer's viewpoint, the use of N+1 parallel redundant rectifier will make the system stable and reliable, in which N is to be kept too small so that the no of parts to be reduced and avoid the failure of rectifiers [15]. Also, you may say that, if we use many devices and machinery, then the chances of the failure of components would increase accordingly. DC power systems that run on the configuration of 48VDC, due to their low discharge rates may utilize back up battery systems for a considerable time. The system only utilizes a bank of 24 cells in series combination and the system is applied at reasonable discharge rate. Whereas an AC UPS system uses considerable no of cells i.e. as much as 120-240 cells in series combination and have a very short back up time of 10-20 mints due to their high discharge rate with per cell discharge voltages may be down to 1.65 V or less [14]. Due to these main differences, batteries are more reliable as back power systems than AC UPS systems.

3.2 Requirements of a Telecom Power Plant

We have concluded some major requirements of a Telecom power plant from [21-23]. The cost must be kept minimum while designing a Telecom power plant. It must be reliable because a break in the power supply interrupts

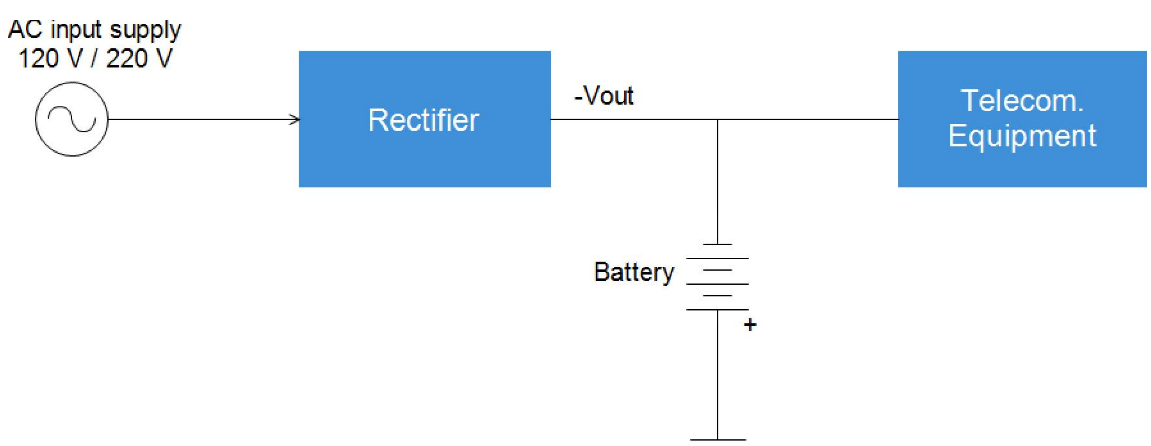

FIG. 2. GENERIC ARCHITECTURE OF POWER SUPPLY TO TELECOM EQUIPMENT

the communication network. It must be capable to meet the normal current requirements of the connected Telecom equipment. A standby power system must be introduced to enable continuous supply. The output voltage must be maintained within the limits specified for the Telecom equipment. A self-protecting system must be designed to tackle the overload and fault conditions. An electrical noise of the plant must be below the specified limits.

4. PROPOSED SYSTEM DESIGN AND OPERATION

4.1 Proposed System Design

Fig. 3, demonstrates the block diagram of our proposed system. This system enables the continuous power supply to Telecom equipment. The grid power gives power to the rectifier which charges the backup batteries. When this power goes down the backup generator starts automatically to run the system smoothly without any interrupt. But in this way, the battery bank is not utilized so much, and generator fuel is being burned. To minimize the cost and give benefit to the Telecom Sector, the system can be designed which can be utilized the battery bank. For this purpose, the smart switch system has been designed and simulated at the hardware level which has a feature to do this all with the help of a microcontroller. We chose Atmel microcontroller ATMEGA8 [24] and PROTEUS [25] software as a simulation tool. Our main focus is to design a smart switch to utilize the battery banks and run the system smoothly. In the case of failure of main power supply, the smart switch will shift the system for getting the power from alternate power supplier such as batteries with the help of EMRs based on automated changeover system.

Now, we discuss each block of the proposed system in detail:

4.1.1 Grid Power/Main Supply

Traditional Telecom equipment is manufactured so that they require input power as AC source with single phase, generally, the available configurations are starting from 120, 220, or 240V with 60Hz frequency, whereas 220-240V single phase AC with 50Hz frequency may also be countered with.

4.1.2 Diesel Generator

DG set are extensively used as both primary and standby sources of power for Telecom equipment. AC DG sets are used at stations for providing a standby power source whenever main AC power supply fall occurs.

4.1.3 Rectifier

Usually, the Telecom equipment requires an input power of -48VDC. These types of power systems have multiple numbers of redundant rectifiers; these rectifiers are here to convert 220/240 VAC input power to -48 VDC output power. AC power is converted into -48VDC using multiple parallel rectifiers.

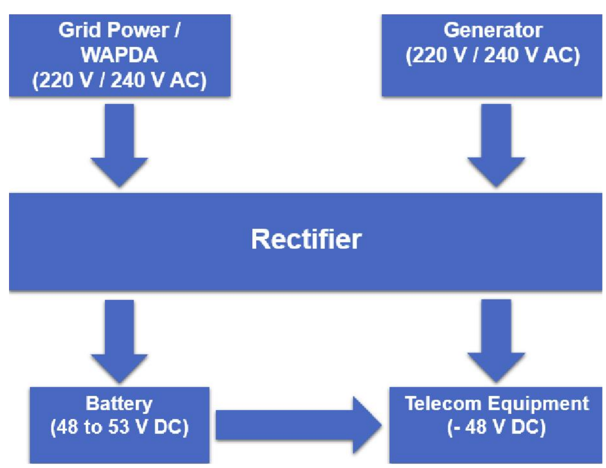

FIG. 3. GENERAL BLOCK DIAGRAM OF THE PROPOSED SYSTEM DESIGN

4.1.4 Battery

On occasion of AC power supply failure or rectifier failure, the essential Telecom equipment should be supported by standby batteries for some period until the main power is restored. Batteries are charged from the output of the rectifiers. Rechargeable batteries are used as a battery bank. Critical load equipment is also powered by this source.

4.1.5 Smart Switch

Smart switches are now extensively employed for the switching purposes, i.e. to route the power from grid power to the backup power system or any other substitutes for the continuous operations. So far, in this paper, a smart switch system has been designed and simulated at the hardware level, which has a feature to control the system operation smoothly with the help of a microcontroller.

4.1.6 Telecom Equipment

A Telecom sector consists of various equipment to provide communication facility for their customers. Telecom equipment is the set of numerous devices and cannot be enlisted. A telephone transceiver set is a very common example of Telecom equipment.

4.2 Software

In this setup, PROTEUS software [25] is used for the simulation purpose because of its more appreciable feature of easily interfacing of microcontrollers with other analog and digital peripherals. The PROTEUS can simulate circuits that contain multiple CPUs (Central Processing Units) by just placing one or more than one microcontroller in the circuit and connect them accordingly. The at mega8 microcontrollers is used in the system design along with different sensing circuits, as well as different Telecom switches are interfaced in the PROTEUS environment. The overall system's operations are controlled by the microcontroller and assembly language is used to program the microcontroller. For that purpose, the μVision IDE Keil software [26] is used for the source code editing and program debugging purpose.

4.3 System Operation

The simulation design of smart switch is shown in Fig. 4, there are three relays RL1, RL2, RL3. RL1 is connected to the rectifier's output 48 VDC, the output of RL1 is connected to the backup battery for charging. When grid power will go down the backup battery will be utilized by the Telecom load. Fig. 4, a comparator compares the battery voltage level. If the battery will be discharged by 45V the comparator's output will be 0V. This indicates that battery must be charged again to give the continuous power to the system. For charging of the backup battery, the microcontroller will give a command to the RL2 to start the DG-set automatically. When DG-set will be started the backup, the battery will be recharged again through the RL1. After half an hour RL1 will be disconnected from the battery and the battery strength will be measured automatically by the comparator. If the battery gets charged by the 49VDC the DG-set will be stopped with the help of RL3.

5. EXPERIMENTAL RESULTS

Experimental work has been performed in Nawabshah Exchange, STR-V Region, PTCL (Pakistan Telecommunication Limited) [27]. The results of our experimental work are described in tabular form as well as in graphical representation.

In Table 1, fuel capacity and consumption of the DG have been tabulated. These values are calculated before the installation of automatic changeover switching system, which shows total consumption of PKR. 1518000/- per month with the average monthly fuel consumption of 13200 litres for DG set having the capacity of 400KVA1. Since our country Pakistan is facing energy crises. So far, the failure of main power happens usually. Hence, alternate power sources must be established for uninterruptible power supply to the Telecom sector. For which, mostly DG are installed as a backup source. But the running cost of generators is more than enough. It consumes a lot of fuel; this statement is justified in Table 1.

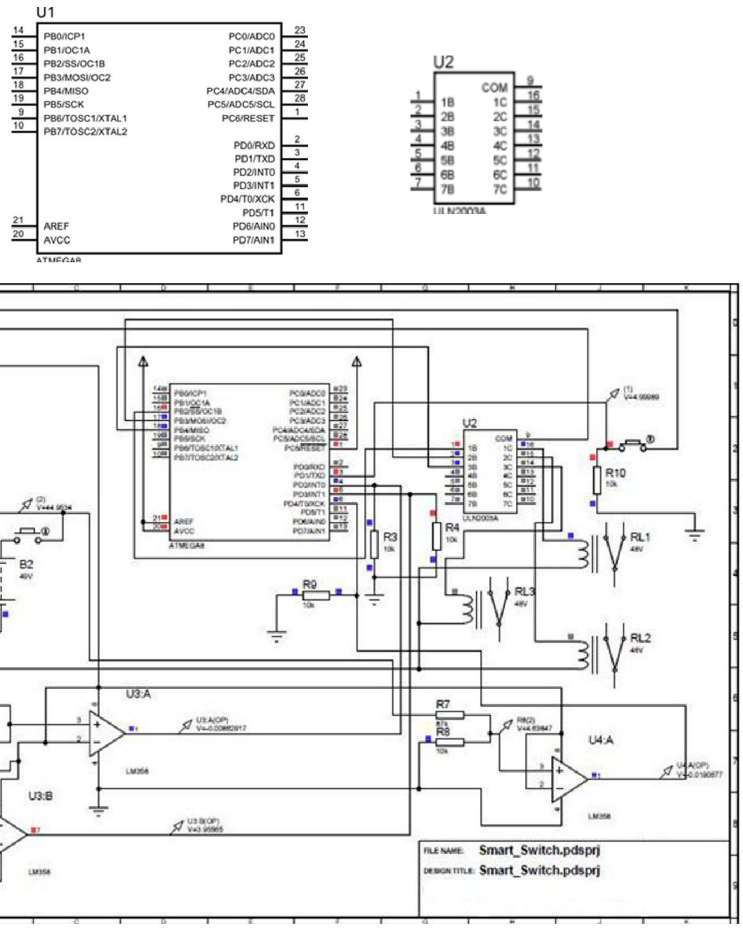

FIG. 4. CO-SIMULATION OF MICROCONTROLLER BASED SMART SWITCH CIRCUIT DIAGRAM

TABLE 1. PRESENT FUEL CONSUMPTION DATA DG SET CAPACITY WISE

Existing Position (Auto Start)									
No.	DG Set Capacity (KVA)	C/H (Litres)	Daily Average LS (Hrs)	Total No. of Phases of LS	Daily Average Running	Daily Average FC (Litres)	Average Monthly FC	Per Litre Cost of Fuel	Total (c/m)
1.	400	55	8	5	8	440	13200	115	1518000
2.	300	40	8	5	8	320	9600	115	1104000
3.	225	33	8	5	8	264	7920	115	910800
4.	200	34	8	5	8	272	8160	115	938400
5.	100	15	10	5	10	150	4500	115	517500
6.	60	10	10	5	10	100	3000	115	345000
7.	50	10	12	6	12	120	3600	115	414000
8.	25	5	12	6	12	60	1800	115	207000
9.	15	3	12	6	12	36	1080	115	124200

In Table 2, cost of operation of DG Set per hour are mentioned. It is noticed from Table 2 that after the installation of soft switching, the monthly consumption is reduced to PKR. 910800/- per month with the average monthly fuel consumption of 7920 litres for DG set having the capacity of 400KVA. The difference in the cost for both cases can be observed from Fig. 5. The smart switch based automated changeover system routes the power from main power supply to battery banks instead of getting power from the DG. The main function of smart switch is to utilize the power from batteries. By utilizing batteries, a lot of fuel of generators is curtailed, ultimately the cost of operation is also reduced as shown in Table 2. By comparing Tables 1-2, it is justified that the fuel consumption of DG is comparatively minimized. When batteries go down, this system starts the DG automatically and utilizes its power with help of proposed smart switch and changeover system. Table 2, different rated DG sets are also listed before installation of automatic changeover switching system.

In Table 3, operation cost of DG set is tabulated. The summary of whole results is represented in terms of a graph is shown in Fig. 5. Hence the goal is achieved and got optimized results. By installing the smart switches in the Telecom power plant, the cost of fuel is significantly minimized.

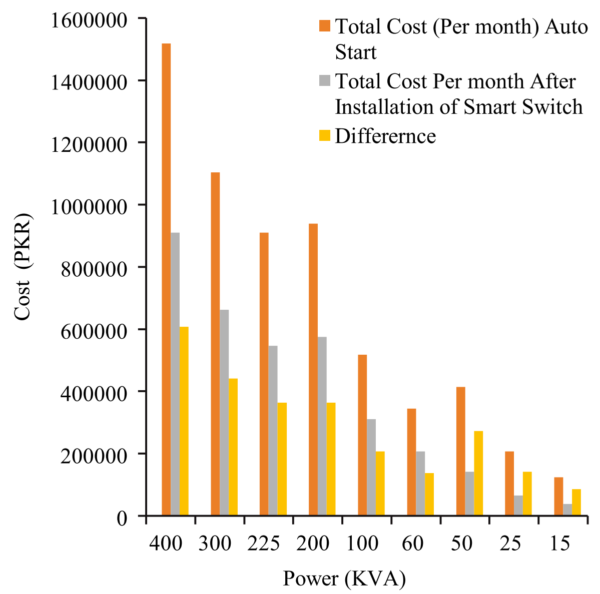

FIG. 5. GRAPHS SHOWING DIFFERENCE AND REDUCTION OF COST

TABLE 2. CHART SHOWING OPERATION COST (AUTO START)

After Installation of Soft Switching									
No.	DG Set Capacity	C/H	Daily Average LS	Daily Average Running (Hours)	Daily Average FC	Monthly FC	Total C/M	Difference	CR (%)
1.	400	55	8	4.8	264	7920	910800	607200	40
2.	300	40	8	4.8	192	5760	662400	441600	
3.	225	33	8	4.8	158	4752	546480	364320	
4.	200	34	8	4.9	167	4998	574770	363630	
5.	100	15	10	6	90	2700	310500	207000	50
6.	60	10	10	6	60	1800	207000	138000	
7.	50	10	12	4.1	41	1230	141450	272550	70
8.	25	5	12	3.8	19	570	65550	141450	
9.	15	3	12	3.72	11	335	38502	85698	

TABLE 3. CHART SHOWING OPERATION COST (AUTO START)

No.	Capacity of DG Set (KVA)	C/H (Litres)	Daily Average FC (Litres)	Monthly Average FC	Amount (PKR)
1.	400	55	440	13200	1584000
2.	300	40	320	9600	1152000
3.	225	33	264	7920	950400
4.	200	30	240	7200	864000
5.	100	15	150	4500	540000
6.	60	10	100	3000	360000
7.	55	8	96	2880	345600
8.	25	5	60	1800	216000
9.	15	4	48	1440	172800

6. CONCLUSIONS

The optimized power plant is very much effective in terms of the cost of operation. The cost of operation is minimized up to 40%, which can be justified from the results, described in the previous section. This proposed system has provided an uninterruptible power supply from the battery banks to the Telecom equipment with the help of smart switching system. Optimal utilization of battery banks within safe limits is also described in this paper. The main advantage of battery banks is to provide an uninterruptible power to the Telecom equipment at the specified limits. The power requirements of Telecom equipment are the maintained to facilitate the customers of a Telecom company without formal delays. This directly impacts on the quality of service of the company, which is the core value of the company. Well, besides power requirements, protection against overload and faults were also located for the betterment of the equipment. Electrical noises were also kept below the prescribed ranges.

This work can also be extended by increasing the reliability of the battery sets and minimizing the propagation delay of the devices. Also, by the implementation of effective sensing and electromechanical devices for good operation, the cost difference can be increased at significant level. This work can also be carried out via other embedded systems.

7. NOMENCALURE

LS (Load Shedding)

FC (Fuel Consumption)

CR (Cost Reduction)

C/H (Consumption per Hour)

C/M (Cost per Month)

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REFERENCES

[1] Kaur, R., Krishnasamy, V., Muthusamy, K., and Chinnamuthan, P., "A Novel Proton Exchange Membrane Fuel Cell Based Power Conversion System for Telecom Supply with Genetic Algorithm Assisted Intelligent Interfacing Converter", Energy Conversion and Management, Volume 136, pp. 173-183, 2017.

[2] Kasper, M., Bortis, D., Deboy, G., and Kolar, J.W., "Design of a Highly Efficient (97.7%) and Very Compact (2.2 kW/dm^3) Isolated AC–DC Telecom Power Supply Module Based on the Multicell ISOP Converter Approach", IEEE Transactions on Power Electronics, Volume 32, No. 10, pp. 7750-7769, 2017.

[3] Chukwubuikem, N.M., Ekene, M.S., and Godwin, U., "A Cost-Effective Approach to Implementing Change Over System", Academic Research International, Volume 2, No. 2, pp. 62-72, 2012.

[4] Kupriyanov, A., "Utilizing Hybrid Power Systems in Telecom Applications", UNIPOWER Powering Technologies, 2016. http://unipowerco.com/pdf/utilizing_hybrid-an.pdf

[5] Ezema, L.S., Peter, B.U., and Harris, O.O., "Design of Automatic Change Over Switch with Generator Control Mechanism". Academic Research International, Part-I: Natural and Applied Sciences, Volume 3, No. 3, pp. 125-130, 2012.

[6] Cugnet, M., Sabatier, J., Laruelle, S., Grugeon, S., Sahut, B., Oustaloup, A., and Tarascon, J.M., "On Lead-Acid-Battery Resistance and Cranking-Capability Estimation", IEEE Transaction on Industrial Electronics, Volume 57, No. 3, pp. 909-917, 2010.

[7] Fakham, H., Lu, D., and Francois, B., "Power Control Design of a Battery Charger in A Hybrid Active PV Generator for Load following Applications", IEEE Transaction on Industrial Electronics, Volume 58, No. 1, pp. 85-94, 2011.

[8] Sachan, A., "Microcontroller Based Substation Monitoring and Control System with GSM Modem", IOSR Journal of Electrical and Electronics Engineering, Volume 1, No. 6, pp. 13-21, 2012.

[9] Belvedere, B., Bianchi, M., Borghetti, A., Nucci, C.A., Paolone, M., and Peretto, A., "A Microcontroller-Based Power Management System for Standalone Micro Grids with Hybrid Power Supply", IEEE Transactions on Sustainable Energy, Volume 3, No. 3, pp. 422-431, 2012.

[10] Mandaliya, H., Mankodi, P., and Makwana, B., "Microcontroller Based DDS Function Generator", International Journal of Engineering Science and Innovative Technology, Volume 2, No. 1, pp. 483-486, 2013.

[11] Thiyagarajan, V., and Palanivel, T.G., "An Efficient Monitoring of Substations Using Microcontroller Based Monitoring System", Volume 4, No. 1, pp. 63-68, 2010.

[12] Socher, G., "A Microcontroller Based Dc Power Supply", Linux Focus, Article Number 251, (Accessed on August 2016).

[13] Shameer, V.H., and Shameer, K.M., "Proactive Condition Monitoring Systems for Power Plants", International Journal of Scientific and Research Publications, Volume 3, No. 11, pp. 1-5, 2013.

[14] Thomas, M.G., "Powering Telecom and Info Technology Systems", Power Quality Archive content from Electrical Construction & Maintenance Magazine, 2001.

[15] Guerrero, J.M., Hang L., and Uceda, J., "Control of Distributed Uninterruptible Power Supply Systems", IEEE Transactions on Industrial Electronics, Volume 55, No. 8, pp. 2845-2859, Aug. 2008.

[16] Fraisse, M., and Buchsbaum, L., "Environment Friendly High Quality, High Availability Telecom Power Plant Architecture", International Telecommunication Energy Conference, pp. 463-469, 2002.

[17] Allen, W., and Natale, S., "Achieving Ultra-High System Availability in a Battery-Less -48VDC Power Plant", International Telecommunication Energy Conference, pp. 287-294, 2002.

[18] Baliga, B.J., "Power Integrated Circuits-A Brief Overview", IEEE Transactions on Electron Devices, Volume 33, No. 12, pp. 1936-1939, December, 1986.

[19] Kolo, J.G., "Design and Construction of an Automatic Power Changeover Switch", AUJ. T. II Volume 2, pp. 113-118, 2007.

[20] Jerry, C.W., "Electronic Handbook", CRC Press, Electrical Engineering Handbook Series, [ISBN: 9780849318894-CAT# 8890], pp. 2640, 2005.

[21] Shirazi, O.H.A., Onar, O., and Khaligh, A., "A Novel Telecom Power System", IEEE 30th International Telecommunications Energy Conference, pp. 1-8, San Diego, CA, 2008.

[22] Kwasinski, A., and Krein, P.T., "Optimal Configuration Analysis of a Microgrid-Based Telecom Power System", 28th International Telecommunications Energy Conference, pp. 1-8, 2006.

[23] Kwasinski, A., and Krein, P.T., "A Microgrid-Based Telecom Power System Using Modular Multiple-Input DC-DC Converters", 27th International Telecommunications Conference, pp. 515-520, Berlin 2005.

[24] ATmega8/L Datasheet (Accessed on July 2016) http://www.atmel.com/images/atmel-2486-8-bit-avr-microcontroller-atmega8_l_datasheet.pdf

[25] PROTEUS 8.0 (Accessed on August 2016) http://www.labcenter.com/download/prodemo_download.cfm

[26] Keil µvision (Get Started) (Accessed on September 2016) http://www.keil.com/uvision/ide_ov_starting.asp

[27] Nawabshah Exchange, STR-V Region, Pakistan Telecommunication Limited https://ptcl.com.pk/