An Overview of Uninterruptible Power Supply System with Total Harmonic Analysis & Mitigation: An Experimental Investigation for Renewable Energy Applications

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Abstract

Increasing gap between power supply and demand causes electricity crisis and excessive load shedding in any developing countries like Pakistan; as well as the power failure due to numerous reasons. Therefore, in such circumstances a short-term and best solution for users in terms of instant and back up supply can be through Uninterruptible Power Supply (UPS); it could be more effective and efficient with hybrid storage source and active power filter. Moreover, the growing trend in U.P.S industry has been observed because it delivers a continuous and clean power supply to critical and sensitive loads without delay or transients; it also offers instant protection when utility power is not available. However, in this manuscript authors discussed brief look regarding UPS types, control techniques and reliability; and also investigate the optimal power transfer for sustainable power source including minimizes the total harmonic distortion (THD) from 46 % to 1.46 % with proposed active power filter (APF), in order to save more than 15 % energy during conversion.

Keywords:

UPS, control techniques, storage sources, renewable energy, active power filter and THD.

1. Introduction

Increasing gap between power supply and demand causes electricity crisis and excessive load shedding in any developing countries like Pakistan; as well as the power failure due to numerous reasons (see Table 1). Therefore, in such circumstances a short-term and best solution for users in terms of instant and back up supply can be through Uninterruptible Power Supply (UPS); it could be more effective and efficient (see Table 2), UPS delivers continuous electric power and protect connected loads from sudden power failure, overvoltage, suppress line transients, under voltage [1].

Table 1: Pakistan power generation and loses.

Pakistan	2014-2015	2015-2016
Installed Capacity	24961	25374
Electricity Generation	108916	111997
Generation Capacity MW	19132	20121
Generation Demand MW	24757	25754
Deficit	-5625	-5633
Maximum Demand (MW)	26475	26462
Population (Million)	189.17	192.82
Consumption	23699982	25663733
Energy Sale (GWh)	89929.48	94353.75
Per capita (kWh)	444	445
Average Sale(kWh)	3070.23	3117.5
Total Losses GWh	**16930.72**	**17385.08**
Losses in %	**18.99**	**18.53**

In power system, UPS has the great importance and increased demand with standards, it provides power during blackouts to critical and sensitive load without delay or transients with instant protection [2]. Power outage is the main problem that could be easily overcome by the installing UPS in backup in order to avoid sudden failure. UPS Supply critical and sensitive loads with uninterrupted supply and quality power in industries, data centers, communication systems, power plant and for hospitals [2]. Table 3 shows the category wise energy consumption and losses in Pakistan.

Table 2: Different distribution companies scenario.

Distribution		**Losses**		**Over-Loaded Transformers (above 80%)**	
Company	**Load Shedding**	**GWh**	**%**	**Nos**	**%**
PESCO	2.3	3968.09	33.8	19,311	31.99
IESCO	3.43	878	9.1	3,105	6.83
GEPCO	4	956.65	10.58	1,548	2.58
LESCO	1.67	2809.95	13.9	41,952	43.23
FESCO	3.5	1220.06	10.2	3,285	3.36
MEPCO	3.2	2422.66	16.4	6,871	4.5
HESCO	3.33	1196.4	26.5	8,336	23.59
SEPCO	4	2374.59	37.72	6,443	18.39
QESCO	2.83	1318.17	23.8	8,696	16.21
K-EL	1.33	4440	22.24	648	2.78

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Table 3: Category wise energy consumption and losses.

Category	Consumption		Consumer	
	GWh	%	Nos	%
Domestic	43,537.29	46.14	22,799,179	84.69
Commercial	7,096.43	7.52	3,258,918	12.68
Industrial	24,977.75	26.47	346,442	1.32
Agricultural	8,525.27	9.04	323,696	1.25
Public Lighting	457.63	0.49	9,924	0.04
Bulk Supply	3,550.90	3.76	4,384	0.02
Others	1,149.49	1.22	852	0
Supplied to K-EL by PEPCO	5,059.00	5.36		
Total	**94,353.75**		**26,743,395**	

UPS structure in redundant groups is used to increase the availability and reliability as well as the protection even if one or more UPSs fails [3-5]. In Table 4, shows the various control schemes dynamic and overall THD including APF performance response is described for UPS

Table 4: Loss of Power in UPS due to conversion.

Provinces	Consumption MW	In UPS Power Loss MW
Baluchistan	1294	91
KPK	2683	187
Sindh	4754	332
Punjab	14,805	1036
Total	**23,538**	**1648**

2. UPS Development Approaches

Table 5 shows the classification of UPS and has been discussed on topological configuration basis:

- Static UPS
  - ✓ On Line UPS: Double Conversion On-Line and Delta Conversion On-Line
  - ✓ Off-Line UPS: Standby and Standby ferro
  - ✓ Line Interactive UPS:
- Rotary UPS
- Hybrid UPS

Power quality means clean and continuity of supply but it is effected when faults, long interruptions, black out occurred, and impact of other linear or nonlinear connected load on system in terms of voltage swells, dropouts, voltage sag and harmonic distortion [2]. in that reasons UPS offers instant protection against the particular faults and deliver power with good quality [3]. In UPS system two approaches has been used; say distributed and centralized.

The distributed approach is highly critical and sensitive for continuous power, several UPS are connected in parallel and flexibly which also increase the reliability due to redundancy [4]. And centralized approach for continuous power single large UPS used in industrial and utility are high cost for redundancy and increases in capacity with connected load. The advantages are low maintenance and service. UPS in parallel controls frequency, active/reactive power load management, stabilizing, regulation of voltage and active filtering [5].

Table 5: Characteristics of different UPS types.

Rating (kVA)	UPS Type	Efficiency	Cost per kVA	Voltage Conditioning	Inverter Operation
5-5000	Double Conversion On Line	Medium	Medium	Good	Yes
5-5000	Delta Conversion On Line	High	Medium	Good	Yes
0-0.5	Stand-By UPS	Very High	Low	Poor	Not
3-15	Stand-By Ferro UPS	Medium	High	Good	Not
0.5-5	Stand-By On-Line Hybrid	Low	High	Good	Partially
0.5-5	Line Interactive UPS	Very High	Medium	If Designed	If Designed

3. UPS Configurations and Redundant

The most effective three redundant UPS configurations are: zone, serial and parallel operation, and can be discussed as follows [5]:

Fig.1 shows the UPS zone operation diagram; each zone has one or more UPS in operation for a specific load, so impact is limited and in case of failure or maintenance load is shifted to other zone.

Many UPSs are connected in cascading form end to end in string if any fails, others will provide power automatically by changing path.

Moreover, in parallel configuration, the system can be used to increased reliability, redundancy, capacity and flexibility as shown in Fig. 3. In this case, the load is shared by all equally, if one UPS fails completely than load will be shifted to another UPS [6-10]. Fig 2 shows the parallel redundant UPS with static by pass switch, in this case the real distributed UPS to supply the loads. The UPS in parallel configuration could be easily isolated. It can be classified as parallel like (N+1), distributed redundant with Static Transfer witch (STS), Tri-redundant (no STS) and system plus system. The best architectures is system plus system 2(N+1), 2N which has highest availability, complete redundancy and eliminating failure at single points.

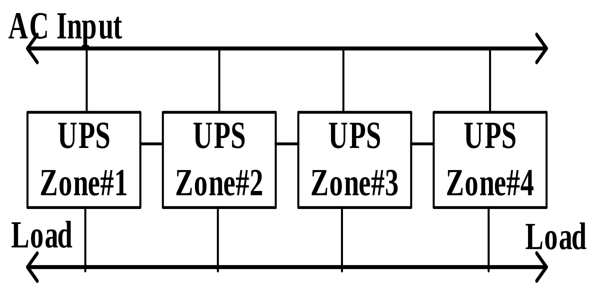

Fig. 1 UPS in zone configuration.

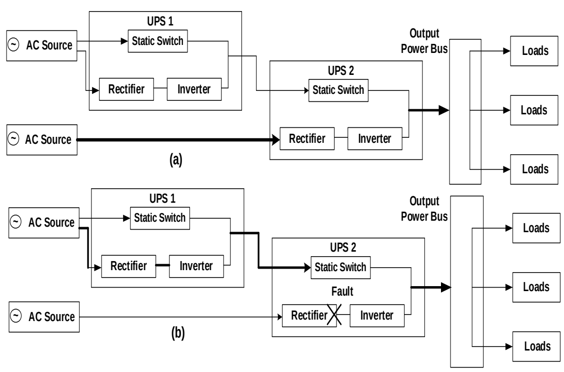

Fig. 2 UPS serial operation (a) system in normal operation (b) system in fail over operation.

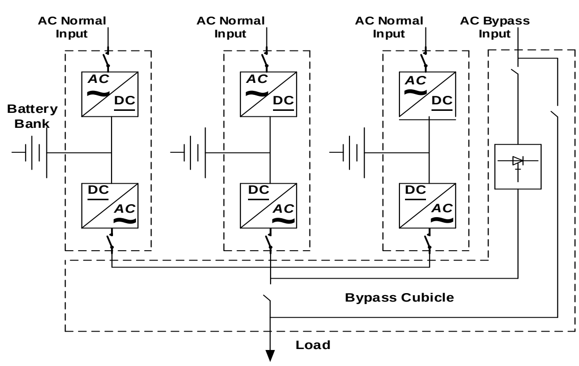

Fig. 3 UPS parallel operation with static-switch cubicle (SSC)

3.1 Parallel Operation of UPS with different Control Strategies.

The control strategies are classified such as:

- ✓ UPS parallel operation with concentrated control, by using Phase Locked Loop (PLL).
- ✓ UPS parallel operation with master-slave control, in (PLL) has been enabled from master unit.

It is observed that the slave units are not required separately in PLL circuits for enabling [4, 10]. Whole system fails if failure occurs in any parallel control circuit.

- ✓ UPS parallel operation with wireless independent Control, in this inverters without inter connected load sharing wires. As unbalance changes system frequency occurs a communication signal will be generated for operation and control between two inverters.

4. UPS Classification based on Control Techniques

The UPS dynamic response and THD of output are most essential performance features and both are influenced by control strategy and topology. Mainly control techniques categorized in single and multi-loop control techniques [6-19] and can be discussed as follows:

4.1 Single Loop Control

In this control technique, output voltage regulation is obtained from feedback loop [6]. For compensation controller, a signal is generated from the deviation between output voltage and reference value, and the design of single loop is very simple as well as cost effective but in unbalanced/nonlinear loads, its performance is very poor.

4.2 Multi-loop System

The multi-loop system has better performance, whereas, its robust and flexible in unbalanced conditions as given in Table 6. In multi-loop system current and voltage stability is obtained through excellent controller performance [8-13]. Predictive control is easy and emerging control technique optimized criteria, it also manages various constraints and non-linearity. This technique is further classified in dead beat and model predictive control [9, 13]. In [8], authors also discussed about repetitive control scheme for the removal of intervallic disturbance [8]. With time delay, unit multiple feedback loops are used that reduces the periodic errors but poor dynamic response, because huge memory is required, and during non-periodic disturbance poor performance observed [13]. But combination of both controller, which provides fast dynamic and great precision tracking capability. In Iterative Learning Scheme adjusted zero deviation. Object to achieve such response without knowledge of system which observed at each cycle and adjusted for repetition [10]. The design process is very complex and used for eliminating followed deviation produced by periodic disturbance.

Table 6: Different multi-loop control techniques features

Control Scheme	Time	Complex	Sensor	Result
Dead Beat Control [9]	Slow	Complex	Output Voltage, Inductive current	Not good
Model Predictive Control [13]	Slow	Simple	Output voltage, Filter current	Good
Repetitive Control [8]	Slow	Complex	Output Voltage	Excellent
Iterative Learning Controller [10]	Slow	Complex	Output Voltage	Excellent
Neural Network Control [11]	Fast	Complex	Output Voltage	Good
B-spline Network (BSN) Control [12]	Fast	Simple	Output Voltage	Excellent

4.3 Non-linear Control Schemes

Slide mode and adaptive control are the best nonlinear controller for UPS inverter control, both have better performance and robust in operation with respect to linear controllers but in implementation, these are more complex. Slide Mode control mostly applied in the inverters and also used for nonlinear load because of high performance, good dynamic response, robustness and stability. The disadvantages includes chattering phenomena due to unwanted oscillation with amplitude and finite frequency that also leads to poor accuracy and higher heat losses [14]. Adaptive Control scheme is used for nonlinear, unbalance loads as well as during sudden load change and having high performance, better voltage regulation, low total harmonic distortion (THD), small steady state error and fast transient behavior but computation complexity is very high.

4.4 Modern Control System

This control system is applicable for any loading conditions, it has small execution time, high flexibility, low cost, and outstanding performance [14-19]. Voltage regulation is provided by outer voltage loop while THD is maintained by the inner loop with high stability. UPS Inverter robust tracking control scheme has been suggested by author for fast tracking performance [17]. In order to minimize delay time caused by calculation and space vector modulation a one step ahead predictor is incorporated. Luenberger type observer is used to estimate or predict the inductor current, unmeasured disturbance and capacitor voltage. A multiple resonant control scheme has been proposed. By using Kalman filter prediction gain is calculated. Under non-linear and linear loads controller has shown better performance with low THD as given in Table 7.

Table 7: Modern control techniques analysis and comparison.

Reference Controller	THD(L)	THD(NL)	Transient (ms)	Complex
SPWM Controller [15]	1.10%	3.80%	60	Medium
Multiple Resonant Controller [16]	-	2.70%	16	Complex
Synchronous Ref: Frame Voltage Control [18]	0.20%	1.68%	1.0	Complex
Fix Switch Frequency Slide Mode Control [14]	1.10%	1.70%	0.50%	Medium
Robust Tracking Controller [17]	0.20%	1.68%	1.0	Complex

5. Storage and Backup Sources for UPS

Storage and backup sources for UPS like batteries, super capacitor and flywheels presented with features high reliability and availability. But the optimal solution is hybrid combination [19, 30-37]. UPS systems plays a very important role and their features have high reliability and availability; both are influenced by the storage and backup sources. Nowadays, the available storage and backup sources are batteries, super capacitor and flywheels. As it has High backup time, large in size, weight, space, high cost. To deliver operating or required current and voltage these are in strings in parallel, in series, or in combination. Mostly nickel cadmium, lead acid, and lithium polymer and lithium ion batteries are used [22, 26] in detail (See Table 4).

However for a very long period backup could not be possible through batteries because charge or discharge cycles. It also contains toxic heavy material like mercury, lead and cadmium, which creates environmental issues as well. Recently, Hybrid solution has gained popularity and it is the combination of power generation and storage equipment (fuel cell, ultra-capacitor) when UPS is connected to batteries which provides best performance in blackouts and any power interruption by providing instant backup power and protection. Different energy storage systems from many reviews have found stressed on the features, composition, and performance [20].

5.1 Flywheels for UPS

It is wheel on rotation which stores kinetic energy and supplies load when main power fails input A.C, flywheel act as an A.C generator (through D.C-A.C). For continuous rotation the wheel is connected to series of motors. It is different from rotary UPS that provides 5-15 minutes of backup where as a flywheel only provides 8-15 seconds of backup for load. Fig. 40 shows flywheel system for longer runtime mostly it is used in conjunction with a stand by generator [20, 21].

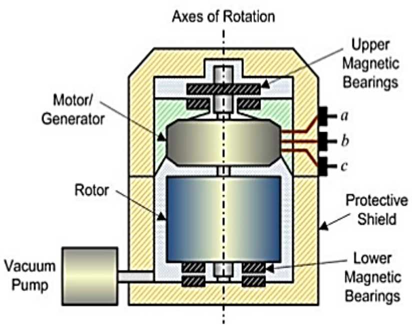

Fig. 4 Flywheel system

5.2 Ultra-capacitor for UPS

A double-layer electrochemical capacitor stores electrical charge temporarily also known as a super capacitor [23-24]. In comparison to common capacitor it stores thousands of times more, require little maintenance, no chemical reactions are required, and it has long-life (8 to15 years), small in size and weighs, large ultra-capacitors with energy densities over 20 kWh/m³ but these provide only two minutes of runtime, High cost and short runtimes are still under development [25].

5.3 Fuel Cell/ Batteries powered UPS system

Hybrid energy source connected to UPS system is presented in the [24, 25]. Sufficient backup is available for load battery bank and fuel cell is combined. In case of interruption hydrogen gas will be provided to fuel cell, which will develop required voltage hence not able to offer instant backup power. Super-capacitor or rechargeable battery could be employed to overcome this problem for instant backup. Hybrid UPS system block diagram in Fig.5 is illustrated [26, 27]. Main energy source is Fuel cell whereas secondary energy sources are super capacitor and Batteries. Through the DC-DC converter Fuel cell is linked to DC-Bus while other sources with common DC-Bus with bidirectional converter which acts as charger and inverter.

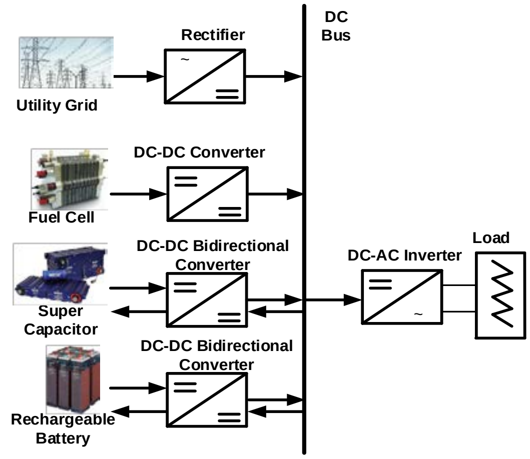

Fig. 5 Hybrid UPS system block diagram

The UPS system circuit diagram with hybrid energy storage is shown in Fig. 6 in which step up voltage of the fuel cell to the D.C-link voltage done through conventional boost converter. In case of power from grid mode it charges batteries and super capacitor with buck operation, through bidirectional converter when main power fails for stable supply in back-up mode (boost mode) both discharges. In literature various bidirectional converters have been proposed with both non-isolated and isolated configurations (see [28, 29]).

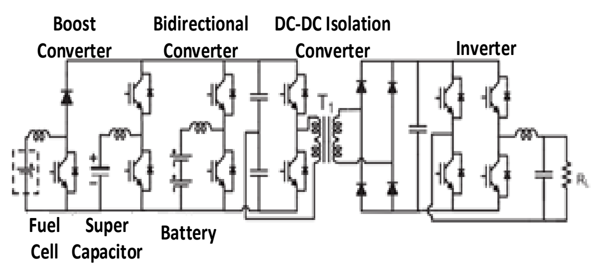

Fig. 6 Circuit diagram of hybrid storage UPS system.

Selection of bidirectional converter depends upon the efficiency, conversion ratio, and system reliability. Load is delivered and regulated output AC voltage through H-bridge inverter. In near future fuel cell is the best replacement to the conventional UPS. Super capacitor prevents transients, fluctuations, slow dynamic. Still few drawbacks of fuel cell technology are slow response time, high cost and sensitivity to lower frequency ripples.

5.4 Supercapacitor-Batteries Dual Powered UPS system

The batteries for UPS system normally provide backup power to load for 5 to 15 minutes until the generator starts and delivers long time backup whereas super capacitor offers backup for 5 to 15 seconds [27]. The Capital cost versus runtime for energy storage methods and comparison of lead-acid battery with super capacitor is shown in Fig. 7.

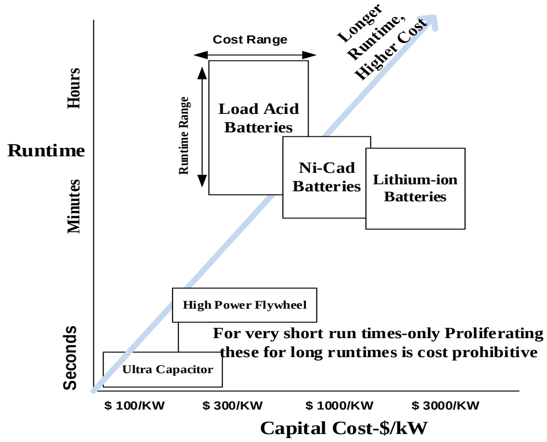

Fig. 7 Energy storage methods by comparing capital cost vs runtime.

Nowadays in order to provide high power and more reliability hybrid system i.e., battery and super capacitor are used for comparison of batteries regarding the size and weight, whereas, super capacitors and flywheels is shown in Fig. 8.

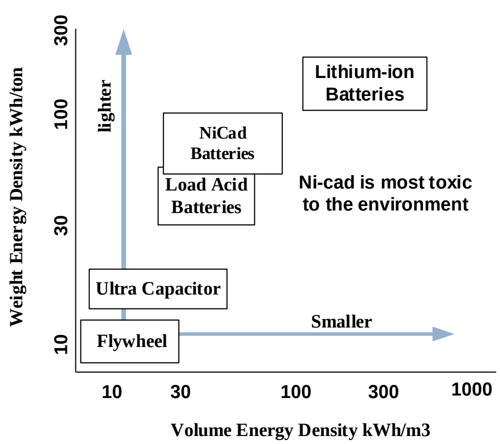

Fig. 8 Batteries, super capacitors & flywheels by comparing size & weight

Reduced stress is observed on battery when in parallel with super capacitor also delivers power during transient demand while batteries deliver during smooth demand. Super capacitor costs very high and it is less developed technology, further research is required in order to decrease in cost and higher performance. The energy storage technology discharge and charge is given in Fig. 9 and property, analysis, comparison is given Table 8.

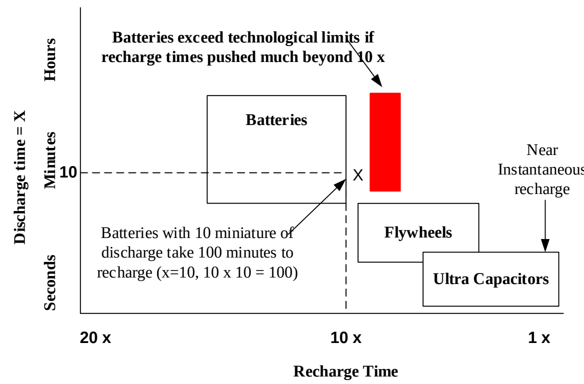

Fig. 9 Discharge and recharge of energy storage technology.

Table 8: Energy storage analysis.

Properties	Chemical Storage Media	Electrical Storage Media	Mechanical Storage Media
	Batteries	Super Capacitors	Flywheels
Typical runtime	5 minutes to 8 hours	10 seconds to 1 minute	1 second to 1 minute
Power range	in MW	<10000 KW	in MW
Operating conditions	Narrow temperature range	Wide temperature range	Wide temperature range
Maintenance	Regular Conditioning	Maintenance free	Regular Maintenance
Initial Cost	Low	Moderate	High
Safety	Significant	operate at high voltages	higher rpm flywheels
Lifetime	1-5 Years	8-14 years	20 Years
Reliability	Moderate	High	Moderate
Maintenance	Moderate	Moderate	Higher
Recharge time	10 x discharge time	Seconds	Seconds or minutes
Discharge cycles	Up to 3,000	Up to 1 Million	Unlimited
Power Density	Low <1KW/kg	High <10MW/kg	Medium
Energy Density	10-100 Wh/kg	1-10 Wh/kg	
Monitoring	Sophisticated	Simple	Included
Modular	Multiple Capacities	Standard, rackmount	50 KW min
Handling	Very heavy	Easy handling	
Failure	Unpredictable	Predictable	Unpredictable
History	Long (many decades)	Short (a few years)	Speed Dependent
Life Cost		Low	Moderate
Environmental impact	More Harmful	Harmful if burned	Harmful if not recycled
Toxicity	Lead, Strong Acid	Non-toxic	Hydraulic Fluids

5.5 Integration of Renewable energy & UPS system

Renewable energy is preferred due to greenhouse effect and global warming. Also in isolated areas the power supply with wind energy and Photovoltaic (PV) is best solution in order to provide more stable, quality and reliable power to the consumers [39-42]. Renewable energy resources could be connected to UPS which can also be further connected to grid [38-40]. In Fig. 10, PV module with UPS system is shown. Using bidirectional converter, super capacitor and batteries are connected to the D.C bus while through the D.C-D.C converter, the PV module is connected to the system [30, 31]. The connected load supplied A.C voltage from inverter and available surplus energy is stored in super capacitor and battery bank. During nighttime or in case of load demand increases from the generation for fulfilling the energy requirements, stored energy is used. For fast, dynamic and power regulation in system Super capacitors are to be added. PV module with UPS system helps in smoothing out load fluctuations, peak sharing, to make an integrated systems with efficient energy management in [32].

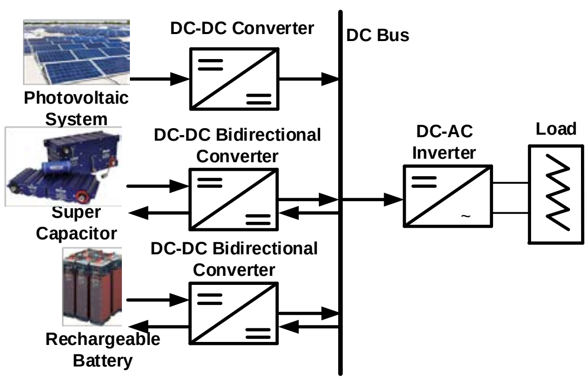

Fig. 10 UPS system with PV module

6. UPS Future Generation in Renewable Energy Application

Nowadays, clean and sustainable energy is added to the smart grid so for Renewable energy Integrated UPS system presented which improves the efficiency, economy and reliability with. Multiple storages and hybrid energy sources [38]. The distributive generation is same category as UPS system provides standby or backup power when main power source failure or interruption occurs and sometime used during peak hours for load sharing, it also increases reliability and cost reduction [33]. For the smart grid an intelligent UPS system is proposed in [34] which is reliable, flexible and energy saving for connecting with Distributive generation (DG) sources. Block diagram in Fig. 11 shows next generation UPS system. High frequency converter in the UPS system allows the parallel connection of the batteries with other distributive generation system to the smart grid. Cyclic use of electrical power between the storage and power grid system are realized in proposed UPS system. It can be useful into hybrid electrical vehicles, auxiliary power supplies, motor drive and distributive generation system due to their modular structure. Line interactive UPS systems have been designed for micro-gird in [35, 36]. The presented system improves the efficiency, economy and reliability of the micro-grids and also export of power into grids in parallel with other distributed generation units for the favorable tariffs. Multiple storages and hybrid energy sources assures reliable power still extensive research is required for intelligent UPS system in order to realize the concept in micro grid and smart grid.

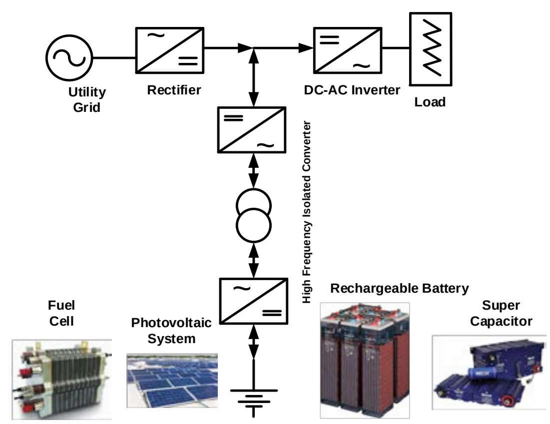

Fig. 11 Block diagram of intelligent UPS.

6.1 Process of selecting a U.P.S system

Many UPS Type and configuration for specific application are available which are the most appropriate according to demand. Selection should be on the basis of technical factors such as: Power rating, Protection, Reliability, Grid environment, Power quality, Power factor, Cost, Weight, Size and Battery bank size. UPS System selection Flow Diagram is shown in Fig. 12. In which there are seven main steps in process for selecting a UPS system [3]. (1) Define the need and application, (2) Calculating power for load (3) Type (4) configuration (5) Protection and Safety, (6) Availability (7) Cost / affordable.

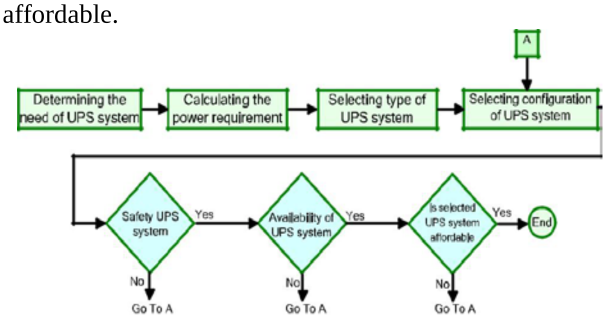

Fig. 12 UPS system selection flow diagram.

UPS type and configuration are determined from protection level and power requirement. For high power application Transformer-based UPS are more appropriate to offer protection even in the disturbances to sensitive equipment through galvanic isolation. For low power applications transformer-less UPS systems are suitable, as these are also cheaper, small size and suitable where there is less disturbance. Cost of UPS increases with complex control system. Hence selection is determined by the balance in the cost and performance [28].

6.2 UPS Cost-effectiveness Evaluation

UPS system cost directly depends upon the capacity, back up time, configuration, type, protection, efficiency and other features like fast switching, automatic monitoring and control functions. Cost analysis becomes easy after completion of six steps. UPS performance is evaluated for the essential features like THD of voltage and current, power factor, transfer time from one mode to other, transient response time and efficiency [32].

7. Harmonic Analysis & Implementation active power filter (APF) for mitigating THD

Poor power quality affects the Pakistan's power capacity thus high THD cause overheating of transformers, unnecessary tripping of breaker, damage the equipment, reducing their useful life [38,43]. In Pakistan, mostly locally made UPS used which have high losses and THD as well poor charging and discharging efficiency as given in Table.9.

Table. 9: UPS Efficiency & THD

In Pakistan Local UPS Efficiency & THD [38]				
Charging Efficiency	Discharging Efficiency	**Overall Efficiency**	**Without Filter THD**	**With Proposed Filter**
79.54%	64%	60.82%	62.758 %	2%

By implementing hybrid active power filter THD could be reduce upto 5%. Fig. 13, active power filter added with UPS for harmonic elimination. As Shown in Table 10 estimated UPS losses reduced from 1648 MW to 1391 MW and save the power about 257 MW.

Table .10: Power saved with active power filter.

Total Power and loss	**TOTAL MW**	**LOSS MW**	**%**
UPS without THD Filter MW Loss	**23538**	**1648**	**14.28 %**
UPS with THD Filter MW Loss	**1648**	**1391**	**0.04%**
Saving of MW with Proposed APF (15% saving)		**257**	**14.243 %**

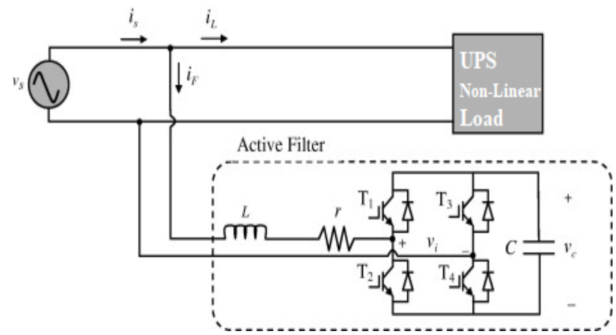

Fig. 13 Active power filter added with UPS.

Mathematical model shown in Fig.14 for the active power filter, the main components are shown while designing active power filter [44-45].

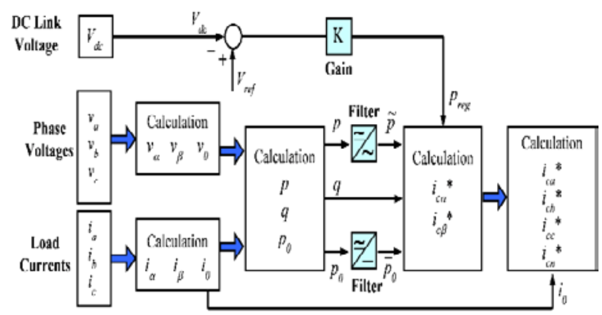

Fig. 14 Mathematical modeling of active power filter.

Simulation results of active power filter for UPS system shown in fig. 15 Source Voltage, Load Current, compensation current and Sources Current shown after active power filter.

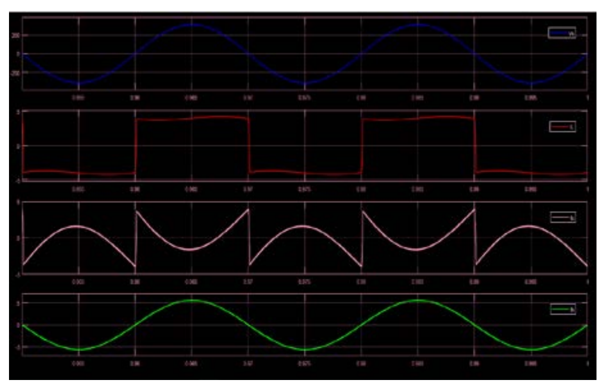

Fig. 15 Simulation results of active power for UPS system.

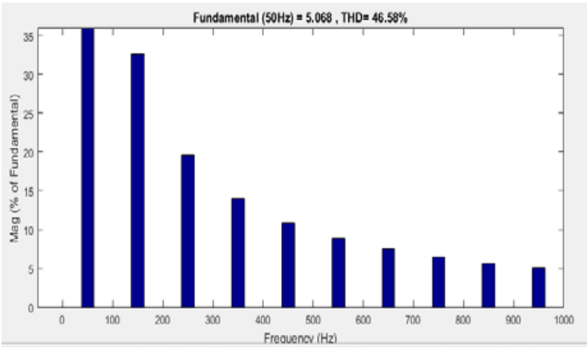

Fig. 16 FFT analysis without active power filter.

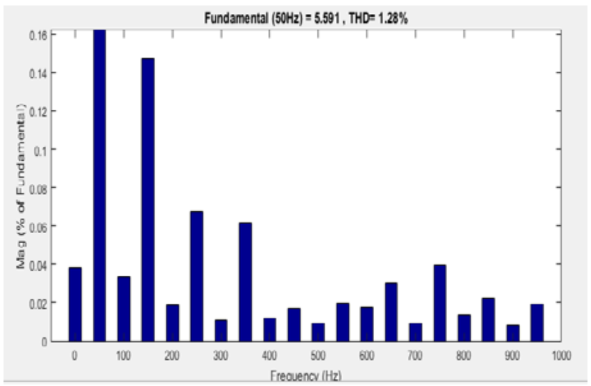

Fig. 17 FFT analysis with active power filter.

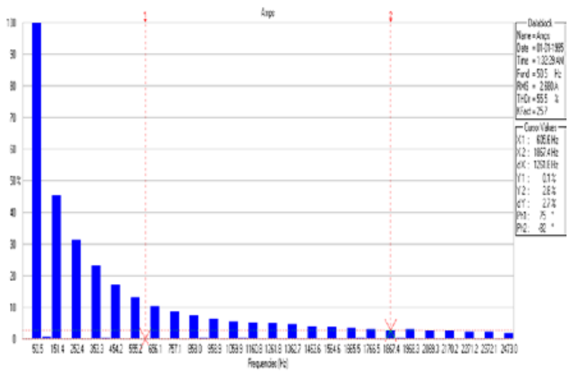

Fig. 18 Real Time THD Analysis with Fluke 34 B.

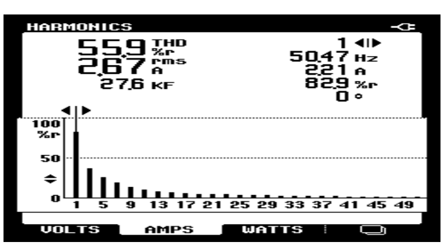

Fig. 19 Real Time THD Analysis with Fluke 34 B.

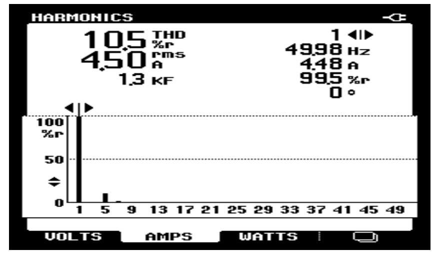

Fig. 20 Real Time THD Analysis with Fluke 34 B.

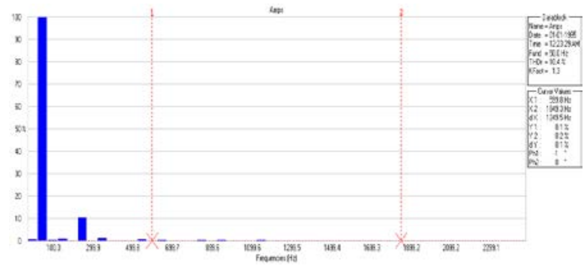

Fig. 21 Real Time THD Analysis with Fluke 34 B.

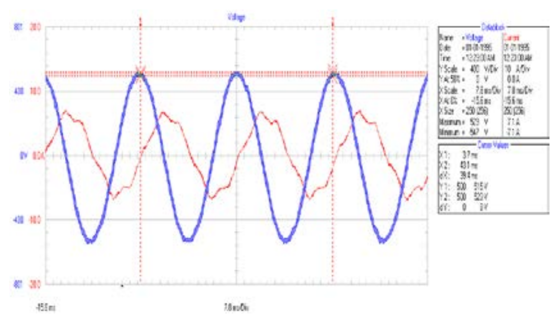

Fig. 21 Voltage and current waveforms & real time THD analysis with Fluke 34 B.

8. Future Direction

With the improvement in the fast switching devices and advanced micro-controllers transformer less UPS systems are available with greater efficiency, high performance at lower costs. In low power applications conventional storage is replaced with fuel cells and hybrid technology. Development is going on for efficient control strategy to attain fast dynamic and transient response, good voltage regulation, low THD and stability with implementation of hybrid active power filters.

9. Conclusion

In this article, UPS systems classification, control strategies, topologies has been explained with their efficiency and performance for renewable energy applications, optimal solution is parallel operation. Model predictive control has the excellent performance for inverter operation. UPS systems with Hybrid storage/backup energy sources and connection to smart or micro grid set a new direction for research. Dynamic stability and reliability achieved from multiple energy sources, also improve the performance of UPS system with proposed APF. In simulation active power filter has improved THD from 46% to 1.4%, hence power lost in conversion process of UPS or chargers could be saved upto 15% or more.

This will be reference for the multiple factions of society such as end users, inventors, researchers, designers, and manufacturers. In any field no doubt research is unending similarly keeping in view the application and importance of uninterruptible power system, the research will remain continue to provide, cheaper, efficient, reliable and best intelligent UPS system to the users

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