INTELLIGENT DISTRIBUTION OF ELECTRICAL POWER WITH SOLID STATE TECHNOLOGY

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Abstract: *Most of the electrical power distribution is in the form of a 3 phase, 4 Wire systems in European countries and South Asian countries like India is at 3 ph, 415 Volts, 50 Hz. Here, in India, most of the pumping loads are 3ph, 415 Volts whereas single phase loads ranging from lighting to Heating, Ventilation and Air Conditioning [HVAC] systems are at 230 Volts. Due to derived single phase supply from 3 phase networks, they are always operating at 5 to 10% extra voltage, albeit rated for 230V, which gives out unwanted additional output from electrical equipment with augmented power consumption at the cost of their reduced life. A new design of power distribution network is proposed here, for a load centre having a demand of 1 MW, with grid connected renewable power back up and power electronic devices. Various tests are conducted on the electrical equipment with voltage and frequency controller to demonstrate their life saving efficient operation and concluded to have a considerable 25% saving in power and a 40% to 50% enhancement in life of equipment.*

Keywords*: Solid State Technology; Solar Photo Voltaics; Power Distribution Network; Power Electronic Devices (PED), Intelligent Power Distribution System (IPDS).*

1. Introduction

Conventional power distribution will have an assortment of loads ranging from single phase Incandescent lamps to a 3 phase pump/compressor sets. Based on the load demand, the supply voltage vacillates between 415 V to 440 V for 3 phase loads and from 230 V to 250 V for single phase loads. The consequences are wastage of power and reduction in life of equipment. Whereas, solid state technology operation is becoming more prevalent, thanks to the readily available high power semi conductors at an economical price with good characteristics and fast switching operations can impeccably regulate these voltage fluctuations and supply distortion free power.

In any distribution system, during grid failure, some of the loads classified as 'emergency or critical loads' derive their supply from a standby portable generator, mostly Diesel Generators (DG sets) in the selected locality. The changeover from the grid supply to standby DG sets takes considerable time [1] which discords with the name critical load. These diesel based generators supply costly power [2] resulting in pollution and diminution of natural resources which does not concur with the demands of saving earth's environment. These drawbacks can be curtailed by installing an Intelligent Power Distribution System; utilising solid state technology and grid connected renewable power like solar.

A model intelligent power distribution system is proposed to a residential area selected from one of the townships owned by an industrial organisation. The total power demand of the area is 1MW [as per the Indian National Productivity Council Survey in the year 2011] encompassing lighting and power loads of 2000 Households, Public buildings, Pump house, Street lighting, Hospital and School (critical load centres). The details of existing distribution scheme and the proposed model for retrofit of existing 25 year old scheme with detailed calculations are presented in the subsequent sections.

This locality is being supplied by a local grid which is getting power from nearby State Electricity Grid which in turn getting power from mostly Coal based Thermal Power plant.

2. Existing scheme

For the location under study, the present power distribution scheme, that was commissioned in1988 and is due now for renovation, is shown in fig 1.

2.1 Normal operation of the existing system

As usual, all the loads derive their supply from the grid (switches S1, S4 to S7 closed and S3 connected to the grid terminal) under normal conditions. Aforementioned voltage fluctuations, in

Fig 1: Existing Power Distribution Scheme

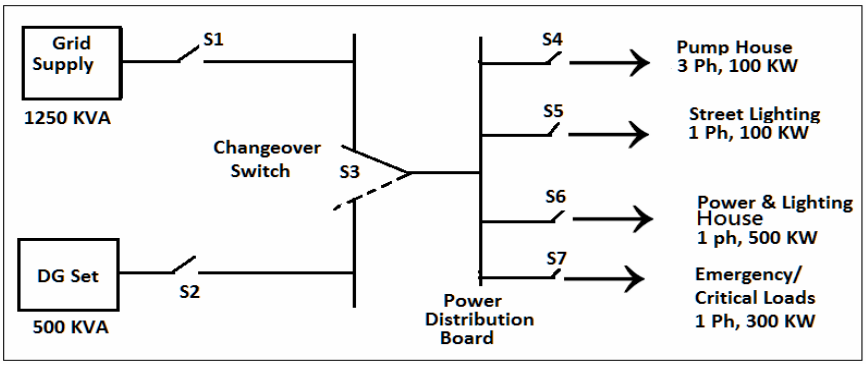
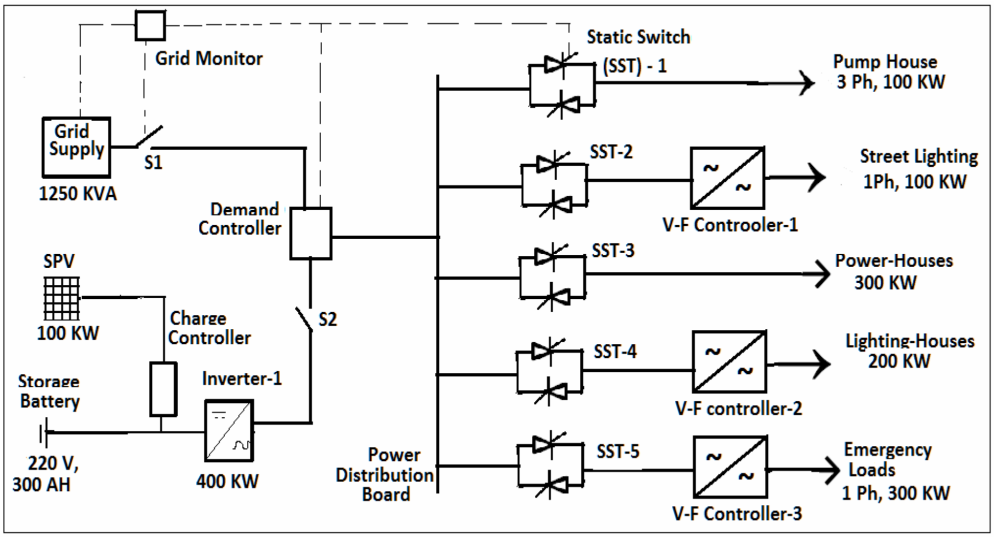


Fig-2: Proposed IPDS Model



both single and three phase systems, are quite common in this condition.

2.2 Grid Fail Operation

During grid failure, supply to emergency loads is extended by DG set (switches S2, S3 and S7 closed, with S3 towards DG Set) with an interruption time of around 3 to 5 minutes; procrastinated by the DG start up and opening of switches S1, S4 to S6 and changeover of S3 to DG terminal. Based on the performance of the DG set and demand on the emergency line, the spare capacity is being used for some of the lighting of main streets and houses with continuous manual supervision. Normalisation of the grid power is also being done manually with a 3 to 5 minute interruption for switching operation.

2.3 Proposal

Most of the switchgear equipment was installed in the year 1988 which are due for modernisation for which an action plan is being prepared to phase out the old equipment. In view of the availability of solid state technology, it is proposed to incorporate power electronic devices and solar photo voltaics with storage battery to transform the archaic distribution system into a remote intelligent network compatible to the present generation.

3 Intelligent Scheme Proposed

The new model should be able to cater the needs of normal as well as emergency loads and changeovers with a minimum possible time and all the operation should be without any manual intervention. The proposed scheme for renovation is shown in figure-2 and its salient features are illustrated.

3.1 Modifications

Existing switchgear components are to be with new components: static switches [3], demand controller, solar photo voltaics with charge controller [4], storage battery, grid monitor and voltage-frequency controllers.

Existing distribution circuit of Housing can be split in to Power (HVAC) and Lighting Circuit. The lighting circuit will supply only the light loads in the house and the power loads by the other incoming.

The DG set can be modestly replaced with green solar power and storage battery which would serve the critical loads whenever required.

3.2 Grid connected operation

Under normal operation of the system all the switches S1, S2 and SST1 to SST5 are closed. Grid supply as well as the renewable power from the solar plant are extended to all the loads through a demand controller. During sunlight hours, solar power is used to charge the storage battery and also share some of the loads when the battery is fully charged. V -F controllers-1, 2 & 3 regulate the voltage and frequency going to single phase loads to maintain exactly the rated values of gadgets as required like 220 V, 52.5 Hz.

3.3 Grid interruption operation

In a few milliseconds through static switches, the grid monitor disconnects the switches S1 and SST1 to SST4 when there is any problem with the grid supply. Such disparate operation, where the static switches take a few milliseconds to operate and the manual switches in the old model take about 3–5 minutes, is very attractive in the new scheme. The emergency loads continue to get supply from the storage battery through Inverter 1, SST5 and V-F Controller-3. Based on the demand, the demand controller will cater the needs of house lighting through SST4 and V-F Controller-2. Only the lighting line to the houses will be served during an emergency situation as it is the basic requirement in case of power outage and the other power loads are of secondary concern. This is a plausible situation only in this new scheme whereas the present archaic system, with only single incoming line, will not be able to accommodate the complete load of all the households.

3.4 Simulations

Both the aforesaid scenarios are simulated for different load conditions at different times of the day and the results are shown in table 1(All the tables are annexed at the end of this paper).

4 Preliminary Experiments and Results

The technical specifications of lamps and other gadgets of reputed manufacturers like Philips, GE and Compton Greaves are reviewed and the following conclusions are arrived:-

- Rated name plate supply voltage of 3 phase equipment: 415 V ± 5%, 50 Hz ± 5%. This becomes 240 V on single phase.
- Declared no load voltage of the grid : 433 V (= 242 V on single phase)

Above values indicate that most of the single phase loads like incandescent lamps, fluorescent lamps and 1 phase motors for HVAC are always running on 5-10% extra voltage than rated. Albeit this high voltage gives more output from the equipment which is unwanted and wasting power at the cost of the life of the equipment [5].

4.1 Experiment on an incandescent lamp

Consider a 100 W Incandescent lamp of Philips make rated for 220 V, 50 Hz which is designed for 1340 lumens [6] or 134 lux in a room of 10 sq.m size. Since the lamp is now operating at 240 V, the light output must elevate to 1760 lumens with 16% increase in power consumption and 60% reduction in life as discussed in [7]. An experiment has been conducted on the aforementioned lamp by extending supply through a voltage and frequency controller and the results are shown in table 2.

These results corroborate the results obtained from the Nomograph [7].

4.2 Some more experiments on fluorescent and HPSV lamps

Tests conducted on a 40 W Fluorescent Lamp of GE make [8] and 70 W High Pressure Sodium Vapour (HPSV) lamp of Crompton Greaves make and ascertained that considerable energy is saved when rated voltage (220 V) is supplied to these lamps unlike deriving single phase voltage (230 – 250 V) from a three phase input supply. The power savings on a Fluorescent lamp is 5% and on HPSV lamp is 18%.

5 CALCULATIONS

For the proposed model of area selected in section 3.0, a study has been conducted to know the loading pattern and possible potential savings with Solid State Technology.

5.1 Power savings calculations

Based on the experiments done, the Energy savings are shown in Table 3.

5.2 Cost estimates of equipment for the proposed model (All the units are in Indian Rupees-INR)

Cost of Grid Monitor & demand Controller	: 1,00,000
Cost of static switches	: 1,00,000
Cost of Inverter-1	: 5,00,000
Cost of Battery & Charge Controller	: 10,00,000
Cost of V-F Controllers	: 10,00,000
Cost of SPV Plant (after state's discount)	: 60,00,000
Total	: 87,00,000
Less (Residual cost of DG Set)	: 7,00,000
Less (Residual cost of SPV after 10years whose life was 25 years)	: 10,00,000
Net cost of new equipment	: 70,00,000 --(1)

5.3 COST OF SAVINGS

i) Annual cost of energy savings as per table-2 @INR 5/ per KWH : 16,42,500--(2)

ii) Annual Savings in replacement of Lamps:

Present replacement cost of Lamps @ once in 2 months : 90,000

Replacement cost with new Model once in 6 months : 30,000

Savings in replacements for 1 year : 60,000 --- (3)

iii) Cost benefit from SPVs in lieu of DG set:

Average running hours of DG Sets per year : 120

Cost of DG power per KWH [2] : 15

Total cost savings from DG set : 5,40,000-- (4)

Total savings for 1 year by ignoring benefits in Relays & Metering and other lamps/ Gadgets: (1) + (2) + (3) = 22,42,500---(5)

Pay back of new equipment= (1)/(5) = **3.12 Years**

This payback is economically viable and acceptable since the payback period is in a single digit even after addition of SPVs whose payback alone will be around 20 years.

There are other intangible benefits with regard to environmental protection from this huge amount of power saving. From standard literature [9–10], it is known that each KWH generated from Coal based Thermal Power Plant:

i) Consumes 0.72 Kg of Coal

ii) Releases 1.1 Kg of Pollutants

iii) Releases 0.3 Kg of Ash and

iv) And Release of 2500 Kilo Calories of heat

In the case presented, for energy savings of 900 KWH per day,

Savings in Coal per annum	: 236 Tonnes
Reduction in Release of pollutants	: 361 Tonnes
Reduction in Release of Ash	: 98 Tonnes
Reduction in Release of heat	: 8,20,000 Mega Calories of heat

The focus has been on developing and deploying technologies to tackle greenhouse gas emissions associated with the use of coal, including carbon dioxide (CO2) and methane (CH4). This scheme will definitely collaborate in achieving this goal.

6.0 CONCLUSIONS

It is experimentally proved with supporting standard calculations that the existing operation of secondary distribution systems can be usurped by solid state technology with significant power savings, affordable payback period, enhanced life of equipment and phasing out of pollutant DG sets. This model can be operated not only for simple renovations but can also be construed for new micro-distribution systems or distributed generation with a reasonable payback period coupled with green power generation. The alleviation of pollutants being released into the earth's atmosphere would help in reducing CO2 emanation, which is main concern of the environmentalists these days.

7.0 ACKNOWLEDGEMENTS

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Table-1: Simulation Results (Ref. to 3.4)

A. Existing Scheme

Time of Day	Source Available		Maximum Demand						Demand met by			Supplied to
	Grid	DG Set	Pump House	Street Lighting	Power House	Lighting House	Emergency Load	Total	Grid	DG Sets	Total	
Mid-Day	Yes	Yes	100	0	100	100	200	500	500	0	500	All Loads
Mid-Day	No	Yes	100	0	100	100	200	500	0	400	400	Emergency Loads
Mid-Night	Yes	Yes	0	100	150	50	200	500	500	0	500	All Loads
Mid-Night	No	Yes	0	100	150	50	200	500	0	300	300	Emergency & Street Lights

B. Proposed Scheme

Time of Day	Source Available			Pump House	Street Lighting	Power House	Lighting House	Emergency Load	Total	Demand met by				Supplied to
	Grid	Battery	SPV							Grid	Battery	SPV	Total	
Mid-Day	Yes	Yes	Yes	100	0	100	100	200	500	400	0	100	500	All Loads
Mid-Day	No	Yes	Yes	100	0	100	100	200	500	0	200	100	300	Emergency Loads
Mid-Night	Yes	Yes	No	0	100	150	50	200	500	500	0	0	500	All Loads
Mid-Night	No	Yes	No	0	100	150	50	200	500	0	250	0	250	Emergency, House Lights

Table-2: Preliminary Experimental Results of Incandescent lamp(Ref. to 4.1)

Volts	Hz	Power (Watts)	Light Output (Lumens)	Lux	Expected Life (Hours)	Remarks
220	50	100	1340	134	1000	Rated Values
230	50	105	1540	154	750	15% extra light with 5% extra power and 25% reduction in life.
240	50	116	1760	176	400	31% extra light with 16% extra power and 60% reduction in life.
250	50	125	1870	187	200	40% extra light with 52% extra power and 80% reduction in life.
220	52.5	99	1350	135	1000	0.7% extra light with 1% less power with same life as designed. **This is the best option.**

Table-3: Power Savings(Ref. to 5.1)

S No.	Load	Rating	Quantity (numbers)	Total Power (KW)	Oper-ating Hours	Total Energy (KWH)@ 220V, 52.5Hz	Total Energy (KWH)@ 240V, 50Hz	Energy Savings@ 220V, 52.5Hz
1	Emergency Lamps-1	100W, 220V, 50Hz Incandes-ent Lamps	1000	100	12	1188	1392	204
2	Emergency Lamps-2	40W, 220V, 50Hz Fluoresc-nt Lamps	1000	50	24	1200	1320	120
3	Emergency Hospital & school equipment etc.,	230V, 50Hz	---	150	8	1200	1320	120
4	House Lighting	40W, 220V, 50Hz Fluoresc-nt Lamps	4000	200	6	2376	2784	408
5	Street Lighting	70W, 220V, 50Hz, HPSV Lamps	400	30	12	336	384	48
					Total Energy savings (KWH)			900