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Intelligent changeover solution for a domestic hybrid power system

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Abstract: **Electricity plays a major role in the modern world as almost all the equipment used is operated using electricity. Electricity demand of the world is increasing day by day and there should be a proper mechanism to meet the growing demand and to improve the efficiency of the power systems while continuously providing power with less environmental effects. This paper presents a changeover solution for a solar-grid hybrid power system that directly focuses on efficiently utilize the power sources by automatically selecting the power source according to the required power demand. Already available automatic power changeover switches in the market are only capable of selecting one source when the other source is not available. They cannot switch the power source considering the power demand. The novelty of this solution is, it can efficiently select the power source considering the apparent power demand of the house.**

Keywords*: Changeover switch, Hybrid system, Instant power supply, Microcontroller based changeover, Solar-powered house*

I. INTRODUCTION

In the developing countries, it is a major issue to provide continuous power supply as the power generation is barely enough to satisfy the peak demand. It is very important to seek a sustainable solution as the electricity demand will only be increased. Nowadays, hybrid power systems can be considered as a better solution for the energy crisis. The hybrid power system is the most efficient system among other power systems which removes the weakness of one source by the other source.

Distributed power sources (on-site power sources) are becoming more popular due to technological innovations, fewer maintenance requirements, access to inexpensive energy resources, and other benefits. Among those renewables, solar power systems are now much more efficient and have become more affordable for residential and commercial customers. As solar energy can be harvested easily, and the system can be maintained easily it would be a better solution to use solar energy for household purposes. The solar panels can blend nicely with the roof, adding style and value to the home and it will not decrease the aesthetical value of the house. Solar energy is a better solution to minimize the electricity bill for most of the middle-class consumers in countries like Sri Lanka. Solar becomes more popular as it is a truly renewable energy source and it is sustainable. Solar is an eco-friendly solution for electricity generation.

The main objective of the intelligent changeover solution for a hybrid power system is to increase the efficiency of the hybrid power system by automatically selecting the power sources according to the apparent power demand of the house. The specific objectives of the system can be classified as follows.

- Provide continuous power supply
- Reduce the number of units consumed by the grid
- Develop the introduced solution to be compatible with the existing power systems

II. LITERATURE REVIEW

As most of the industries require a continuous power supply for their operations, they use backup generators to ensure continuous power supply. If there is a failure in mains supply electricity, the changeover switch, switches the load to the auxiliary power supply, and return back to the mains supply when it is restored [1].

Although there are several types of changeover switches in the market, mainly it can be categorized as the manual or automatic. In a manual changeover switch, the user has to move a lever in the switch to change the power source. This is usually associated with time-wasting as well as it can happen hazards like an electric shock. In order to reduce the stress of manually switching and eliminates the delay, an automatic changeover switch was introduced. It ensures the smooth and immediate power changeover between the main supply and**.** auxiliary supply by sensing the interruption in the main supply. There's no method to efficiently switch the power sources in the hybrid power system with considering power demand.

The hybrid power system is an integration of two or more conventional and non-conventional power sources. The main benefit of the hybrid system is it can mitigate the risk of power outages due to the diversity of power supply. Some examples of hybrid power systems are Solar and Wind, Solar and Grid, Solar and Generator, Solar, Wind and Generator, Grid and Wind, Grid and Generator, etc.

Solar and Wind hybrid system includes an aero generator and solar photovoltaic panels that offer several advantages over a single system. It can generate electricity during day time and also night time. When the sun is strong, the temperature is high and the wind is weak and vice versa. Solar and Wind hybrid system is suitable for city lights, communication base station, and monitoring systems and user's service in remote areas. Weaknesses of the Solar and Wind Hybrid are very complicated due to complicated control strategy, not efficient and not suitable for house premises [2]

[2] introduces an automatic power changeover switch that can automatically switch the alternative power source (generator or solar). If one supply is not available it will be switch to the other source and it will be switch back to the grid when the grid is restored. This is only a solution for power outages and it does not efficiently utilize power sources.

Basically, there are three types of solar power systems,

- Off-grid solar power system
- Grid-tied solar power system
- Hybrid solar power system

As the name implies, there's no connection between the off-grid solar system and the grid. The design of the off-grid solar system varies according to the load requirement of the place in which it is mounted. This system can be used as a solution to the power requirement of remote areas where gird transmission and other power sources are uneconomical. The main drawback of this system is batteries can only store a certain amount of energy. The people who are using off-grid solar power should change their power usage patterns to make off grid-solar more cost-effective solutions [3].

The grid-tied solar power system is a development model of a solar power system that is connected to the utility grid. When the system generates more power than the usage of the house, the surplus energy is sent back to the utility grid. Here power meter is used to measure the power flow in both directions (solar to grid and grid to the house). The electricity bill will be calculated only for the net electricity consumed or transferred during the total billing period. As grid-tied solar doesn't have storage facilities it is less expensive than the off-grid solar systems. The main weakness of this system is if there is a grid cut off, the system cannot be operated due to protection issues.

There were various methods propose to efficiently utilize grid-tied solar power systems. The controller-based grid-tied solar power system integrated with Instant Power Supply (IPS) ensures the continuous power supply through the Instant Power Supply module which provides power to the load when the main grid is not available. Here, solar energy has been considered as the priority and the battery will be charged using the power from solar. The surplus energy is coming from the solar provided to the grid, depending on the load variation. If solar power is not available, then it takes power from the grid. If grid supply is not available, it takes power from the instant power supply (IPS). People can get rid of load shedding because this system ensures continuous power flow[4].

Although this system ensures the continuity of the supply, some developing countries do not give provision for net metering[5].

Solar and grid hybrid system is a combination of off-grid solar and grid-tied solar systems. Hybrid solar systems generate power in the same way as a common gird tied solar system but use special hybrid inverters and batteries to store energy for later use. It has the capability to supply power during grid cutoffs. As there are two power sources, the weakness of one power source can be mitigated by the other power source. The solar-grid hybrid system is more efficient than the other power sources.

III. DESCRIPTION OF THE PROPOSED SYSTEM

The paper introduces a microcontroller-based changeover system to efficiently utilize the hybrid power system. The hybrid power system includes two power sources, grid supply, and solar power supply. According to the battery percentage, availability and apparent power demand of the house, changeover switch will switch to the best power supply at that moment. The introduced changeover system can be operated automatic mode or manual mode.

Automatic mode: Changeover switch will be automatically select the better source considering the power demand, battery level, availability. This solution will also operate as an instant power supply.

Manual mode: User can select the desired power source using a remote controller and he will be able to override the automatic mode. Instant power supply mode will also be operated in this mode.

The process of selecting the better power supply represent in the fig 1 flow diagram.

A. When the grid is available

If the battery level is more than 25%, the control unit will check the apparent power demand of the house. If it falls in between consideration range (higher than the lower limit and lower than the upper limit), the controller will turn on the inverter and supply solar power to the house. Otherwise, the controller will select the grid supply to the house.

The upper limit and lower limit differ from house to house. The lower limit value is chosen by considering the lower demand of the house when all the major electrical devices are turned off. By setting the lower value, the loss from keeping the inverter on for lower demand will be eliminated as the inverter will be turned off and the power will be taken from the grid. The upper limit value is chosen by considering the maximum output of the inverter. This value is set for the safety of the inverter.

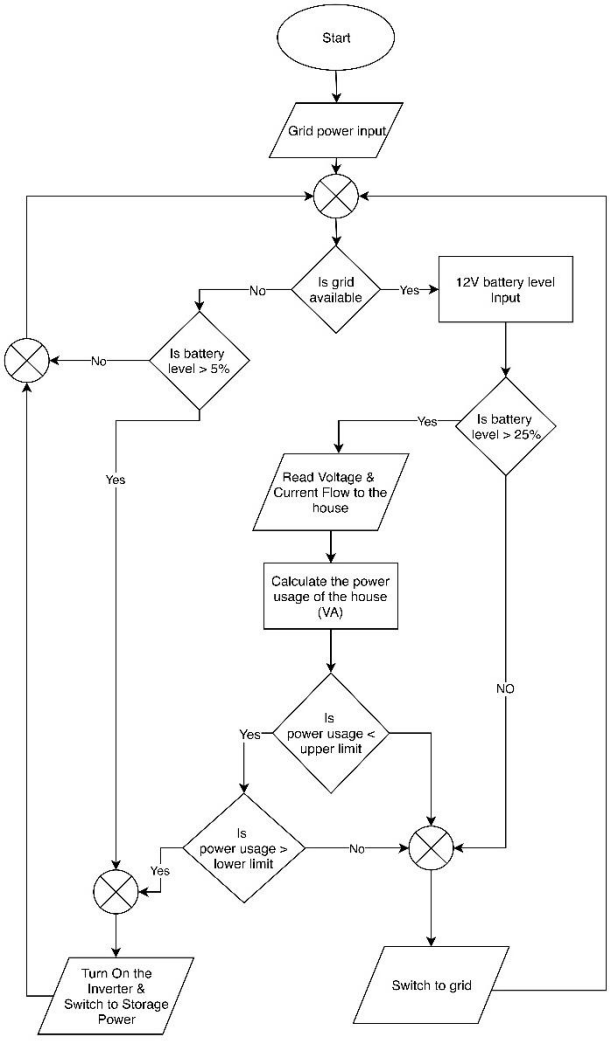

Fig. 1. Flow diagram of the unit

A separate port is given in the system to add external batteries to the system as per the user requirement.

B. When the grid is not available

When the grid supply is not available, the controller unit will select solar power (stored) to the house. If the user needs to connect a separate generator, it can be added to the generator connecting port in the system. If the power interruption from the grid lasts for a long time, an alarm will indicate the low battery level. Then the user can turn on the generator which is connected to the generator connecting port. The controller unit can switch the power source from solar to the generator without interrupting the supply to the house. Fig. 2 indicates the connection diagram of the entire unit.

1) *Solar panel*: The objective of the solar panel connecting to the system is to promote the green energy generation. The number of units generated by solar PV depends on the size of the solar panel, efficiency, weather, and seasonal variations. As per the diagram, the battery is charged by solar power. The solar regulator connected between the solar panel and battery in order to control the charging current of the battery. Battery capacity should be adequate to store the daily harvested energy from the solar panels.

Daily energy harvested by solar panel

$$= W \times 3600 \times h \quad (1)$$

Total battery storage capacity

$$= E \times 12 \times 3600 \quad (2)$$

$$W \times 3600 \times h = E \times 12 \times 3600$$

$$W = 12\ E / h \quad (3)$$

Where,
W = Wattage of panels (W)
h = Average solar energy harvesting hours per day (h)
E = Battery capacity (Ah)

This introduced unit offers three packages to the customer. Customers can select an appropriate package according to the power requirement of the house.

TABLE I. SPECIFICATION OF THE CUSTOMER SELECTION

Package	**Battery capacity (Ah)**	**Wattage of solar panels (W)**
Standard	90	200
Custom 1	180	400
Custom 2	210	460

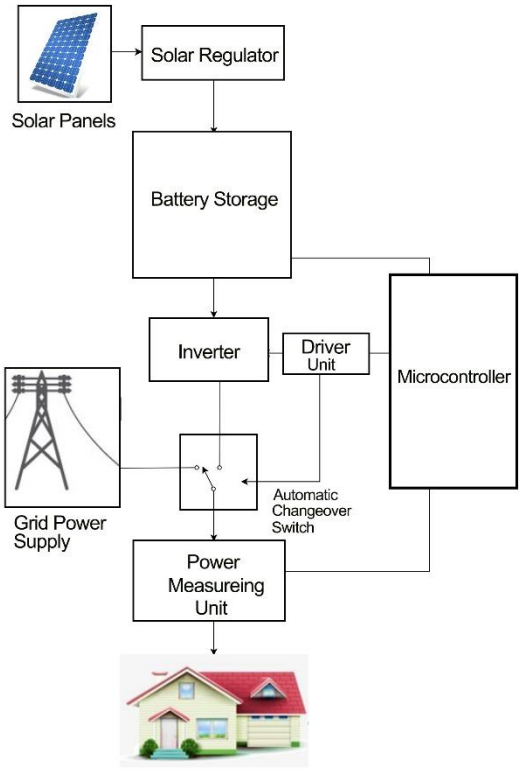

Fig. 2. Connection diagram

2) *Battery:* The system is tested by 12V, 90Ah lead-acid battery.

3) *Inverter:* The function of the inverter is to convert 12VDC into 230VAC. Because all the household appliances used in Sri Lanka operate at 230VAC.

4) *Power measuring unit:* The function of the power measuring unit continuously measures the current and voltage of the consumer end in order to calculate the apparent power demand of the house. The current and voltage measurements of the power measuring unit continuously feed to the microcontroller.

5) *Microcontroller:* The current and voltage of the house and battery voltage feed to the controller unit continuously and the controller unit calculates the battery percentage and apparent power demand of the house. Then the controller unit will analyze the apparent power demand of the house and the battery level to choose the best source for the home at that moment.

6) *Driver unit:* The function of the driver unit is to make the interface between microcontroller and changeover switch.

7) *Universal power adapter:* The introduced changeover switch can easily install to an already wired house without changing the wiring of the house through a universal adapter.

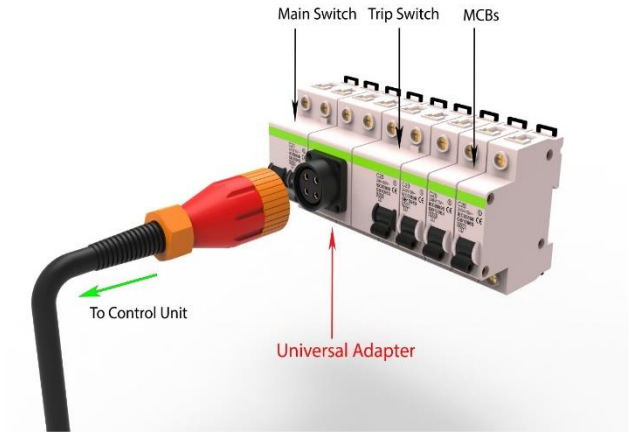

Fig. 3. Universal power adapter

C. *Universal adapter installation to an already wired house*

Fig. 4 shows the wiring diagram of the normal house. The universal adapter can be installed between the main switch and trip switch as shown in fig 5.

IV. Implementation

Considering the implemented separate units, they have to be installed as one unit to be attractive and increase the compatibility. Lead-acid battery should be installed within the system and that consumed considerable space in the final hardware unit. A separate transformer and an inverter also mounted in the unit. The casing of the unit should withstand for the weight of the component and for the easy installation process, separate adapter ports were mounted on top of the unit to connect the solar panel and the Grid supply. The separate transformer was mounted on the circuit board to identify the grid supply is available. For the microcontroller and for the transistor switching circuits, separate 12V and 5V inputs were used. For the changeover purpose 12V, 5 pin relay was used that could withstand up to 50A current.

For the demand measurement, Hall-Effect current sensor was used and calibrated for 750W load. Using the current sensor and voltage sensor, the microcontroller will decide to change the power source to the best available power source to the unit. That will increase the battery lifetime and act as an instant power supply. Then the consumer will not face power outages due to the Grid Supply. As the solar panel is always connected to the unit, the 12V battery will be charged using solar power and all switching processes will be done as the system will automatically change the power supplying source, also the user could identify the mode of operation which the system has selected. For the separate modes of operation, three colored indicator light was mounted and programmed to display separate colors (RED, GREEN, BLUE) for each operating mode. The user could easily identify the working status by the indication color even he is far from the unit.

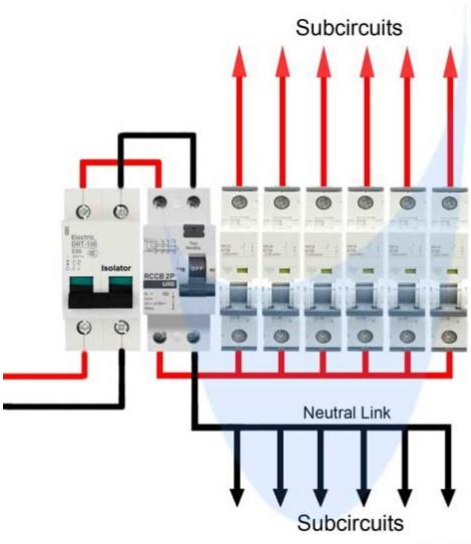

Fig. 4. DB Wiring layout before the installation

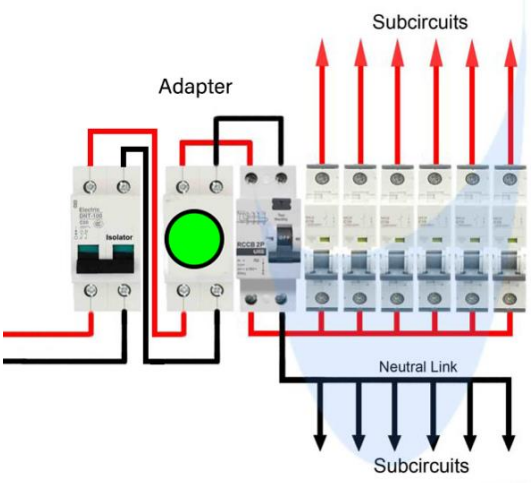

Fig. 5. DB Wiring layout after the installation

The switching mechanism is done using a relay between two power sources. The separate transformer has to be

installed to supply the 12V requirement for the controlling circuit. Live wire for the consumer is passed through a current sensor and the current value is checked using Arduino microcontroller. As the power is proportional to the magnitude of the current, the power sources can be changed considering the magnitude of the current (A) that flows to the consumer end. As the circuit has to be mounted in one unit, the pieces of equipment are assembled as follows.

After the assembling of the circuit, the unit was mounted on a plastic box as follows and the adapter ports, display, indicator light were mounted on the top surface of the box. 4-pin adapter was used to bring the power from the distribution board and feed them back to the Distribution Board (DB), after adding the proposed solution. A separate 2-wired port was added to connect a solar panel to the system and that can be selected by the user as the requirement and the cost. Apart from the above circuit components, the receiver for the remote control operation was connected with the micro-controller for the remote control operation.

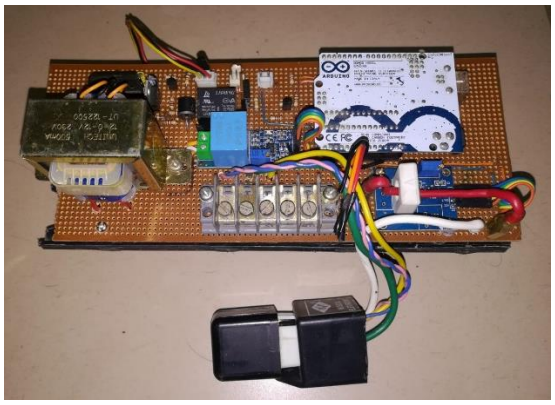

Fig. 6. Main circuit board

TABLE II. IDENTIFICATION OF CURRENT STATE

State	Indicator color
When grid supply is available and working on the grid	Red
When grid supply is available and working on solar power	Blue
When grid supply is not available and working on solar power	Green

This solution could be operated using a remote controller. The supply will not be disturbed as the relay will be switched to the available power source when one source is not available. Users can only turn on or turn off the inverter only if the grid supply is available. The selected power source will be displayed on the LCD display which mounted on the unit. That LCD display will indicate the following operating details.

- Battery voltage
- Battery charging percentage
- Currently operating power source
- AC voltage
- AC current

The user can easily understand the operating status and the battery status from the LCD display. If the Grid Supply is not available for a longer period that could drain the battery, an alarm will be activated from a buzzer that was connected to the inverter. The user can identify the situation and connect a separate power source (Generator) if needed. The alarm will be automatically activated when the battery percentage is 20 % of the full capacity.

All the equipment was assembled into a plastic box (30cm*40cm*50cm) and installed the battery into the bottom half of the box. The introduced solution could be placed near the Distribution Board and connect to the house wiring system using the universal adapter that is placed in between the main switch and the RCCB. As the equipment is connected before RCCB, no safety issues will be there.

Fig. 7. The LCD display and indicator connection after installation

Fig. 8. Assembled complete unit (Included 90Ah Battery)

V. RESULTS

All the measurements were taken considering the standard package that is consists of (200W solar panel, 90Ah lead-acid battery and 1kW inverter. The usable power supply as an instant power will depend on the required power

consumption. For the required consumption, usable hours can be calculated using the following equation.

$$W \times h = 90Ah \times 12V \quad (4)$$

Where,

W = Required power consumption

h = Usable hours

The changeover delay time was measured and observed that there were two delay times for two different conditions.

- Changeover delay when both supplies are available - 150ms
- Changeover delay when sudden disturbance to the grid - 200ms

VI. Conclusion

In the introduced system "Changeover Solution for a Domestic Hybrid Power System", two different power sources (grid supply and solar power supply) were considered and selected better power source accordingly considering the demand for a house. The best available option was selected considering the output current and the battery voltage from the 12V battery and the availability of the power sources. This can be used as an instant power supply. The user will not be disturbed by small power outages from the grid. As solar energy is used as a power source, the monthly electricity bill will also be reduced after the installation of the unit. This is a compatible upgrade for a house wiring system and the introduced unit should be installed as a separate unit using an adapter between main switch and RCCB in the distribution panel. The unit was tested using different loads up to 1kW. The load capacity depends on the capacity of the inverter. The introduced unit saves battery life as it does not allow large loads on the battery at normal conditions. Maintenance of the unit is also low and the system can be isolated from the domestic power system easier than the available power solutions. This unit can be remotely operated using a remote controller and override the manual operation.

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