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Optimized Solar Energy Systems for a non-Outages Grid (Residential Homes - Case Study)

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ABSTRACT: Although the industrial revolution changed the course of history in addition to its non-negligible merits it created and added salient environmental troubles. The energy challenge has become the most effective one in this century that led to many global conflicts. Environmentally friendly solutions in accompanied with a stable non outages grid are becoming most prominent than ever. Solar power is broadly acknowledged as a green technology. This paper proposes a configuration for a hybrid photovoltaic non outages public grid energy system. The proposed system provides a smart integration between the solar and public grid, where the supply sustainability and the optimal cost are considered. This configuration allows the two sources separately or simultaneously supply the loads depending on photovoltaic extracted energy. Operational analysis of the proposed system will be discussed in this paper. The system consists of solar cells, charge controller, batteries and an inverter plugged to a PLC controlled automatic transfer switches (ATS). The system grantee a safe and reliable load feeding independently on the grid status. The system durability is the most depicted feature through the modeling and experimentally results. A typical case studies of two years of non-outages photovoltaic-grid hybrid supply (the implemented system) will be presented and discussed.

KEYWORDS: Solar cells, Charge controller, Batteries, Public grid, Private grid, ATS, MPPT, PLC, and Inverter.

I. INTRODUCTION

Unfortunately the situation in Egypt not only is exceeding the limits but almost enter the danger with a pollution index of Egypt comes second in worst air quality classification. Looking for a natural environment without pollutants and sustainable energy solutions to preserve our own for the future generations[1-2]. Other than hydro power, wind and photovoltaic energy holds the most potential to meet our energy demands alone, wind energy is capable of supplying large amounts of power but its presence is highly unpredictable as it can be here one moment and gone in another, moreover it high cost. Solar energy is present throughout the day but the solar irradiation levels vary due to the sun intensity and unpredictable shadows cast by clouds, birds, trees, etc.[3]. Now the cost of solar power is lower compared to the previous time. The world map for solar radiation rate and availability in Egypt and the world as shown in fig.1 urged us for use[5]. Moreover, the price of producing solar energy is becoming lower than before due to the frequent uses for it. Allot of people use this particular clean energy after the sharply increasing in the accounting slice of energy.

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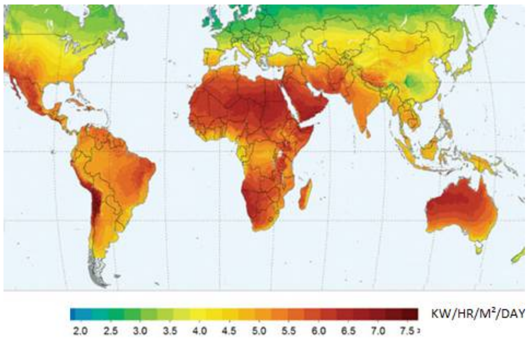

Fig.1. World map for solar radiation

The common inherent drawback of wind and photovoltaic systems are their intermittent natures that make them unreliable so it is important to be controlled as well as integrated with other more sources as batteries [6].
Two experiments with different specification was implemented, the first experiment using 520 Watt polycrystalline photocells and 20A/24DCV PWM charge controller produced 2600 W/Day, the second experimental using 520 Watt mono-crystalline photocells and 20A/24DCV MPPT charge controller produced 3120 Watt/day, more different kinds of loads as lights, motors, compressors, etc. to obtain accurate results. The second experience was the best it efficient than the first experiment by more than 17% of the first experiment.

II. THE PROPOSED SOLAR ENERGY CONVERSION MODEL

The model of the proposed non outages hybrid grid-photovoltaic solar energy system which consists of the PV solar panels, charge controller, batteries bank, PLC controlled ATS panel and inverter as shown in fig.2.

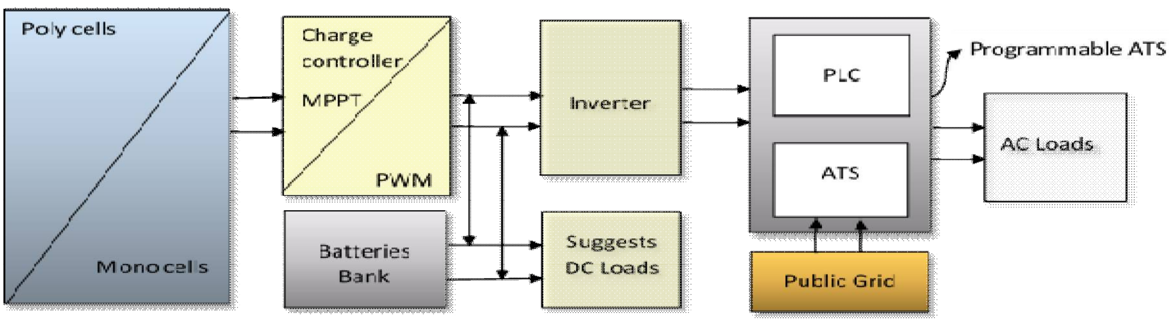

Fig. 2. Block diagram of the proposed solar energy system connect to the public grid.

The system behaves as a load demand optimizer, where the load can fully supplied by the solar energy in case of the public grid outages[7]. In case of regular operation, solar energy and public grid are available; when the load demands are lower than the extracted solar energy the system will direct these extra energy into the batteries bank through the charge controller but when it lower than load then compensate power from batteries as in fig.2. Furthermore, the proposed system is designed for a non-outage 12 hours long at full load with OFF grid. The system suggest DC utilizations loads such as the heat application for future smart homes. The next section discuss the PLC controlled ATS. Batteries bank can modeling by Thevenin's equivalent circuit as shown in fig.3.[13].

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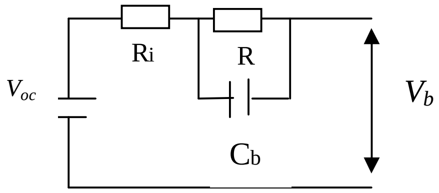

Fig. 3. Theremin's equivalent circuit of the battery

The equivalent capacitance c_b is given by

Cb = (KWH *3600*1000) ⁄ 0.5 (Voc max – Voc min)

Where
C_b equivalent capacitance.
$v_{oc\ max}$ maximum open circuit voltage.
$v_{oc\ min}$ minimum open circuit voltage.

III. PROGRAMMABLE ATS SYSTEM

In spite of fixed relay system (non programmable) ATS is working efficiently in many applications it could causes some delay. The research and development of non-outages loads are full field to improve the ATS performance as in fig.4.

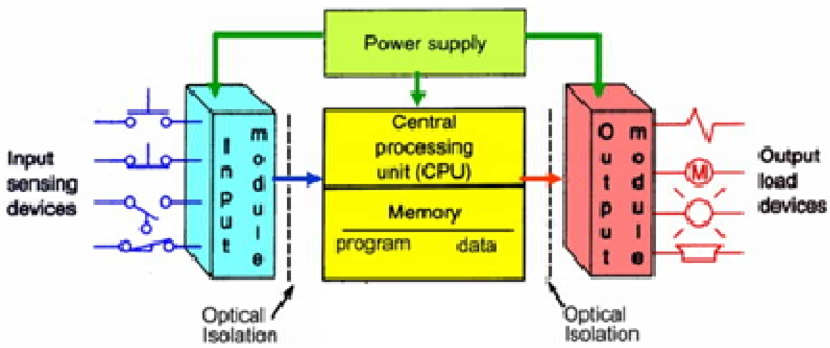

Fig. 4. PLC System block diagram.

The Delta PLC 32 In/Out, 7 outputs and 18 inputs is used for an interactive ATS. The different ATS scenarios will configured later.

IV. PROPOSED CONCEPT FOR THE HYBRID LOADS SECTIONS

The PLC control ATS allows to make an integrated system of domestic energy management depending on the accumulation between the solar and the public utility grid. The system divides the home into three distinctive sections. As shown in fig.5

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Fig.5. Apartment proposed sections.

Section 1 will depend mainly on the solar energy, the other two sections are fed from the public utility grid automatically. The system is designed to switch the source automatically, triggering design and PLC program as shown in table. 1.

PLC Switches	Sec 1		Sec 2		Sec 3	
	K1	K2	K3	K4	K5	K6
No– utility	OFF	ON	OFF	ON	OFF	ON
No– Solar	ON	OFF	ON	OFF	ON	OFF
Automatic	OFF	ON	ON	OFF	ON	OFF
Manual	ON\OFF	ON\OFF	ON\OFF	ON\OFF	ON\OFF	ON\OFF
No-Solar, No-Grid	OFF	OFF	OFF	OFF	OFF	OFF

Tab. 1. PLC status design.

In case of the outages public utility grid K1, K3, and K5 contactors are switched OFF and the solar energy contactors (K2, K4, and K6) are switched ON but in case of no-solar energy, all the loads are connected automatically to the public grid. The system also offers the manual controlling capability as shown in PLC program in appendix A.

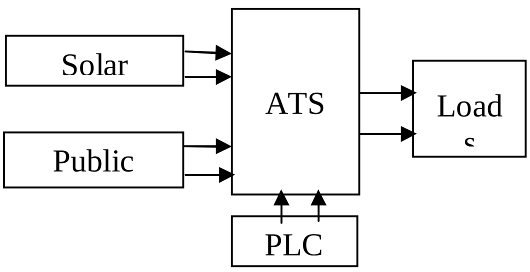

Fig. 6. PLC controller

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A solar energy system integrated with public grid through ATS as shown in Fig.6 includes the power feeders from two grids to the localized loads, while the control connection will be depicted in Appendix A.

A simulation Matlab model of a photovoltaic (PV) residential home system connected to the electrical utility grid has been discussed and presented in [11]. The PV array consists of one string of 12 /165 W modules that are connected in series. The inverter is modelled using a PWM-controlled single-phase full-bridge IGBT module (H-bridge). The initial input irradiance to the PV array model is 165 W and the operating temperature is 25º.

V. ENHANCED PERFORMANCE OF THE PLC CONTROLLED ATS

The PLC controlled ATS allows a real time optimized operation of the hybrid solar-grid system. In this work the PLC program is developed for maximum solar energy extraction. A lot of months typical reading of the grid meters with the normal operation of the targeted apartments displays clearly the flexible soft selectivity between either public grid or solar supply. One can grant much more shares of the solar energy of the proposed system w.r.t grid.

VI. DESIGN CRITERION OF THE NON OUTAGES GRIDS

Uninterruptible home power supply can be configured using different schemes. One of the promising alternatives; the hybrid photovoltaic-public grid power system. The reliability and the non-outages constrains of the proposed system leads to start the system design by calculating the typical loads demands. Case study of the most public residential homes demands are discussed in Table 2. The whole system is shown in fig.7.

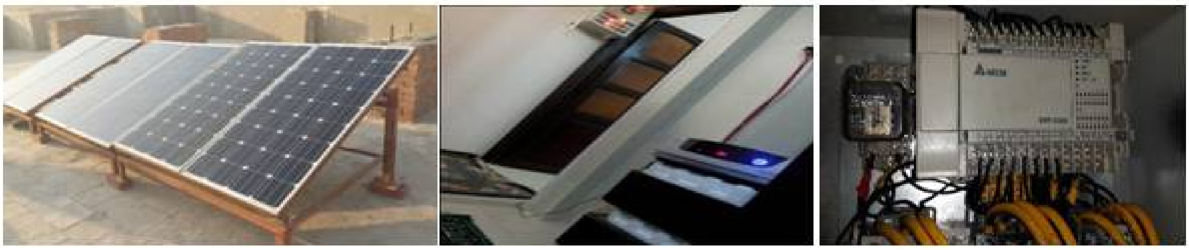

Fig. 7. Implementation of the proposed system.
{Solar panels, (ATS,Invertwe and Batteries), Delta PLC}

No.	Statement	Pwer W	Qty.	Duration Hr	Power/day
1	Led lamps	9	2	24	432
2	Led lamps	9	7	12	756
3	Heater	500	1	2	1000
4	Boiler	500	1	1	500
4	Fan	65	2	9	1170
5	Router	10	1	24	240
6	Refrigerator	-	1	24	1500
7	T.V 32"	100	1	9	900
8	Mobil charger	10.5	3	6	189
9	Dishwasher	-	1	24	700
10	Washing machen	1000	1	1	1000
Total		Average home consmption 8387 W/DAY (350W/Hr) ±10% .			

Tab. 2. Egyptian residence unit load analysis.

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The whole system contains 2000 watt PV solar panels, 20 Ampere 420DCV charge controller, two batteries bank 150 A/HR, PLC controlled panel and 3000-watt inverter this system can deliver power of about 10 KW/Day.

VII. PERFORMANCE PARAMETER OF THE SOLAR SYSTEM

The rated and the prices of the system components at 2014 are listed in table .3. The duration of full loaded system has been obtained exprementaly by a full load operation and fully OFF Grid. The system grants a successiffly load operation for 12 hower. However the non-outages supply demandes is the most dominat an of this work, one can consider a partially non-outages supplies. For axample the non interruptable supply duration of the proposed system can be extreemly extended with a smart load mangement system (LMS). The system output current was stable about 2 ampare within the full load duration as well as 220 V system output voltage [11].

No.	Statement	Qty.	Characteristic	Price	Notes
1	Solar cell	4	130 W	2860	
2	Charge controller	1	20 A	140	
3	Inverter	1	1500 W	800	
4	Battary	2	60 A/HR	1140	
5	ATS	1	-	1000	
6	Els.	-	-	200	
Total				6140	

Tab. 3. The prices of the solar energy system components.

One of the objectives of the proposed system is to reduce the bill of electricity consumption. This is done by transferring part of the loads to the solar energy system to be in a lower accounting slice. With the importance of taking into account the lower cost of the proposed system and how to compensate what was paid during the appropriate period so design theproposed system 520 watt in table 3, the best thing is to produce power for it about 3120 watt/Day but lack of sunshine means the worst case that no produce power. Another objective for this system that life time for full loads which are 4 led lamps, TV, Refrigerator, Fan, Router and Mobil charger about 12 Hr withowt outages table 2 (Egypt Home). Slice electricity consumption for this apartment, according to the bills in third slice 55 piasters in Egypt (North Cairo Electricity Distribution Co.). Therefore equivalent to the annual consumption 704 EP/Year.Then through 8.7 years the system can recover its cost but when the consumption is more than 1000 KW monthly, the system will cover its cost through 5 years.
When we apply this system in commercial or industrial units, it will cover its cost in 4.8 years.

VIII. SYSTEM ANALYSIS AND THE LOAD OPERATION

The consumed power in (watts) of the operating loads home started to be measured in January 2014 only utility grid supply. From January 2015 to January 2016 the meters reading is obtained for the proposed hyprid solar grid/utility grid supply.
Couple of years results comparison of the reaized hybrid system.
The two years results have been carrying out for two interval, the bills are obtained and calculated. On the second interval of (2014 to 2015), the solar energy system was inserted in parallel with the public grid through the PLC controlled ATS system. Table 3. includes both the resuls of the two interval total results in Appendex B.

Grid metres of the targeted appartements		Estimated solar power
2014 – 2015	2015– 2016	1280 KW
3539 (KW)	2259 (KW)	

Tab. 3. The resuls of the two interval.

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Reviewing the incoming data for the previous Table.3. The measured data shows the difference in consumption reducing due to the presence of the solar energy integrated with the public electricity network.

IX. CONCLUSION

A cost and non-interruptible optimized hybrid solar-grid system is proposed, simulated and realized. The system is simply working with ON/OFF grid. One of the systems aims to utilize the maximum permissible extracted energy from solar cells. The second aim is the sustainability of the process where the battery bank is designed to cover the daily load requirements by using new connection (parallel grids). The system ATS is configured for an automatic navigation between manual or automatic switching. The system model has been implemented and tested using the Matlab Simulink packages. Two years, the electricity bills have been displayed clearly cost reduction that are sometimes reach more than 35% of the only grid supply.

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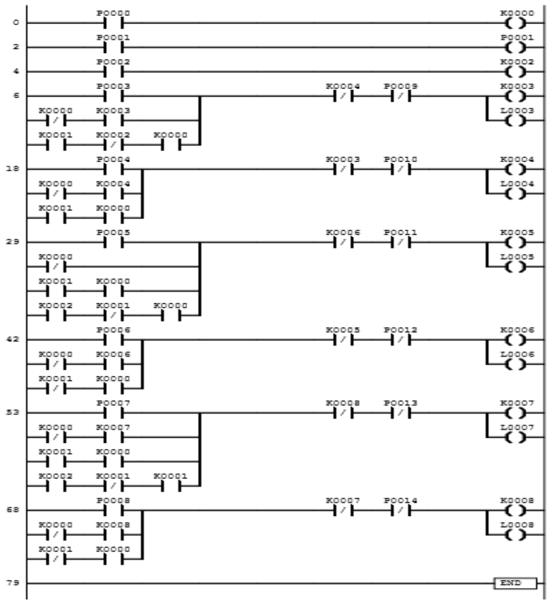
APPENDIX A



The PLC program

APPENDIX B

Nº	Apartment	Power	3059005	3060000	Total	3059005	3060000	Total	Total
	Year		2014	2014	**2014**	2015	2015	**2015**	Year
	Month		without	without	without	with	with	with	produced
1	January	KW	101	100	**201**	72	93	**165**	36
2	February	KW	136	140	**276**	67	72	**139**	137
3	March	KW	119	128	**247**	67	77	**144**	103
4	April	KW	110	127	**237**	54	70	**124**	113
5	May	KW	105	122	**227**	69	88	**157**	70
6	June	KW	95	124	**219**	77	78	**155**	64
7	July	KW	246	240	**486**	90	92	**182**	304
8	August	KW	94	195	**289**	103	96	**199**	90
9	September	KW	248	268	**516**	127	148	**275**	241
10	October	KW	147	160	**307**	120	133	**259**	54
11	November	KW	131	127	**258**	102	139	**241**	17
12	December	KW	121	155	**276**	92	133	**225**	51
Total		KW	1653	1886	**3539**	1040	1219	**2259**	1280

The consumption value (KW) from the bills of electricity consumption through 2014 and 2015

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APPENDIX C

The bills of electricity consumption through 2014 and 2015 are available for two apartment.