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Control Management for Hybrid System of Solar and Batteries Bank Cells - Diesel Generator using Programmable Logic Controller

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Abstract: - This research is studying the management proposition for a hybrid system with solar, batteries bank, and diesel generators using PLC, which is generating the wanted electrical energy and conveys it to the load. This arrangement can be utilized in various places that have sunny days most of the year when the solar light is within a reasonable amplitude, then the solar cells or generator is beginning to supply the electrical energy to the load. if there is any error that has happened or the solar light is not within the working range then the solar-green generator is discontinued, and the batteries bank will start supplying the electrical energy to the load. in case both the Solar and batteries bank are failed, then the diesel generator will feed the load with electrical energy.

Keywords: Diesel generator, Solar-green generator, Batteries bank, and PLC.

I. Introduction

Renewable energy, such as solar energy, has a major role amid the need for electric energy, for many reasons, including high gas prices, severe environmental pollution, and severe climate changes that we are witnessing around the world. This requires us to find alternative resources to produce electricity, such as renewable generators including solar energy to produce electricity, whether in the city or remote areas. Especially the latter, where the cost of constructing electric power transmission lines is very expensive, so the need for an effective renewable energy source for this purpose, with a reliable control device with a means to connect to it remotely, is one of the ideas for making this paper.

Concerns about climate change and the increase in demand for electricity due to, among other things, an ever-growing population, necessitate efforts to move away from conventional methods of energy production. Rising carbon dioxide levels in the atmosphere caused by the use of fossil fuels are one of the factors causing ongoing climate change. Switching to renewable energy will produce energy with a smaller environmental footprint compared to fossil fuel sources. [1].

The currently used solar energy is very marginal—0.015% is used for electricity production, 0.3% for heating, and 11% is used in the natural photosynthesis of biomass. In contrast, about 80–85% of global energy needs are met by fossil fuels. [2].

The necessity of finding new renewable energy forms is extremely relevant and urgent today. That is why mankind must find alternative sources of energy to provide a clean and sustainable future. Within this context, solar energy is the best option among all alternative renewable energy sources due to its widespread accessibility, universality, and eco-friendly nature [3].

In 1897, Frank Shuman, a US inventor, engineer, and solar energy pioneer built a small demonstration solar engine that worked by reflecting solar energy onto square boxes filled with ether, which has a lower boiling point than water and was fitted internally with black pipes which in turn powered a steam engine. In 1908, Shuman formed the Sun Power Company to build larger solar power plants [4]

Renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services. About 16% of global final energy consumption presently comes from renewable resources, with 10% of all energy from traditional biomass, mainly used for heating, and 3.4% from hydroelectricity. The solar panel is the power source of all photovoltaic installations. Photovoltaic (PV) are solid-state, semi-conductor-type devices that produce electricity when exposed to light. Many hand-held calculators run off power from room lights, which would be one example of this phenomenon. The maintenance of the plant is controlled by a Programmable Logic Controller (PLC) [5-6].

II. Methodology

Fig. 1 shows the solar sensor connection to channel two by the loop-powered method (4-20) mA. The solar sensor controller is connected to the solar sensor as shown below. 4 - 20 mA equals 10 - 16 V. Where the positive depot

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of the solar sensor controller is linked to the positive terminal of the solar sensor, the negative depot of the solar sensor is linked to the positive depot numbered three of channel 2, slot three. The negative terminal numbered four of channel 2; slot 3 is connected to the negative terminal of the solar sensor controller. Solar radiation is used for measuring broadband solar irradiance as well as solar radiation flux density, which means that they measure the power of the heat and light from the sun.

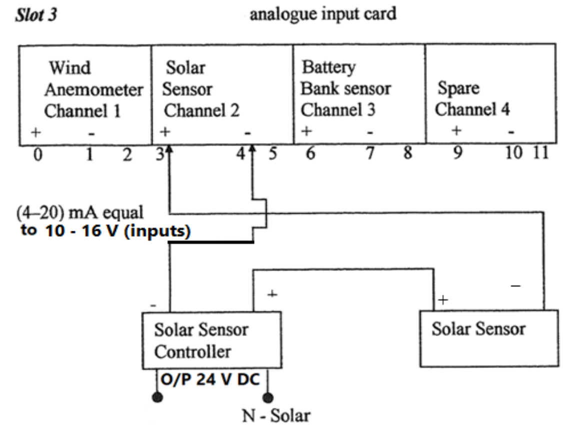

Fig.1: the Loop Powered Method for Solar Sensor.

Fig. 2 shows the connection for the battery bank voltage sensor to channel three by the loop-powered method (4-20) mA. The output voltage from the battery bank voltage sensor controller is 24 VDC. Where the positive depot of the battery sensor controller is linked to the positive terminal of the voltage sensor, the negative depot of the voltage sensor is linked to the negative depot numbered six of channel 3, slot three. The positive terminal numbered 7 of channel 3, slot 3 is connected to the negative terminal of the battery bank voltage sensor controller.

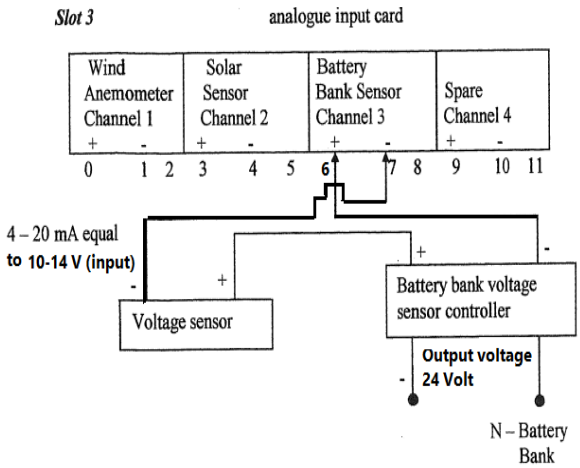

Fig. 2: The Loop Powered Method for Battery Bank Voltage Sensor.

Fig. 3 shows PLC outputs from slot four, terminal 0 of slot 4 is empty and considered a spare. Terminal 1 of slot 4 is connected to the interface relay's coil R2, which means that terminal 1 represents a control voltage, if this voltage is present at any time will cause the contact of R 2 to close. Causing the supply 24 VDC (X3-cont.) supplies the coil of the solar contactor by the contact of R 2, and due to this, solar contactor operation is completed and due to this, the voltage of 24 VDC is feeding the inverter via solar overload device. Terminal 2 of slot 4 is connected to the interface relay's coil R3, which means terminal 2 represents control voltage, if this voltage is present at any time will cause the contact of R 3 battery bank relay closes, causing the supply 24 VDC (X3-cont.) supplies the coil of the battery bank contactor by the contact B_B con. of R 3, and due to this, battery contactor operation achieved and the voltage of 24 VDC is feeding the inverter via B_B overload device.

Both solar Cells (green generator) and battery bank generators are connected in parallel to increase the electrical energy delivered to the inverter and afterward to the load. In case of any failures in solar and battery bank generators occurs, then the diesel generator will be activated according to the control program and terminal 3 will send 24 VDC to R4. Causing the diesel generator's contactor to energize and due to the process will let the diesel contactor activate and let the 240 AC supplied AC bus bar A1.

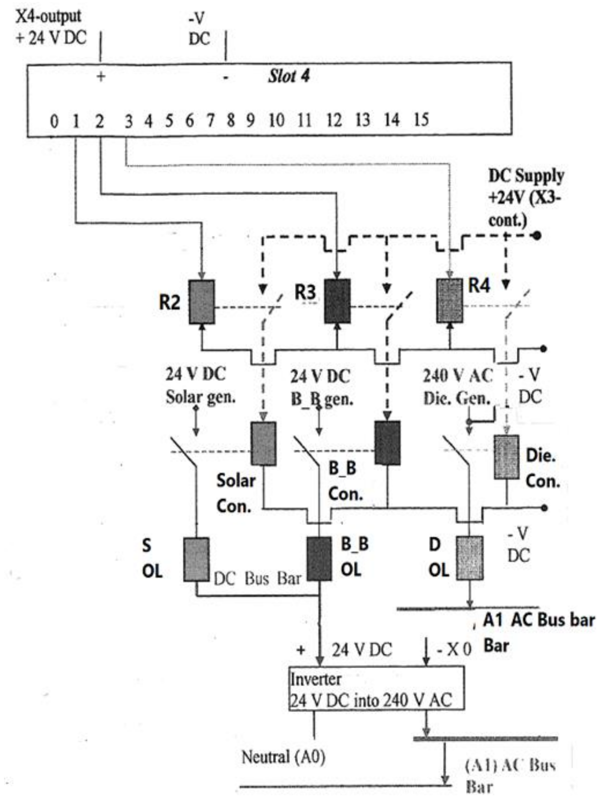

Fig. 3: Slot 4 (outputs) and Final Control of DC and AC Voltage.

Fig. 4 shows that in the ordinary process of the solar cells (Solar generator), bit 3/17 and bit 3/18 both are not actioning (under range and above the domain rates), then PLC's order to scale the readability of the light and heat of the solar tracer N9: 14 (source) and transports it to the proposed N9:1. PLC does the scaling relying on the rate and offsets between the tabulated domain in voltage and input amount in mA of the solar sensor.

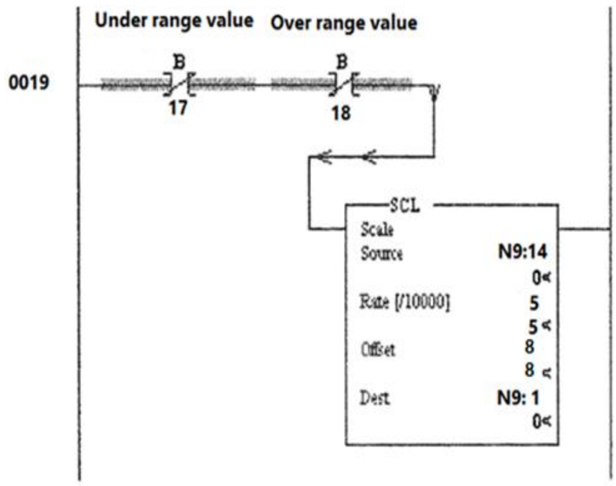

Fig. 4: Scaling the input of the solar sensor

Fig. 5 shows if below and above range values b3/20, and b3/21 are disrupted (no alarm for under and over range flag) then scale instruction will read values from the analogy sensor (source) located in integer file N9: 13 and transfers it to origin spot, integer file N9:2. Shifting this data performed by finding the rate and offset values from the linear relationship between the scaled range (10-14) V DC and the input value (3277 – 16385).

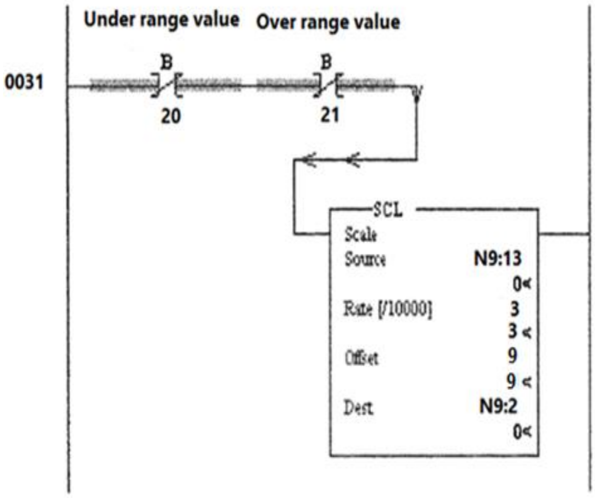

Fig. 5: scaling the input of the batteries bank voltage sensor.

Fig. 6 shows the structure of the input/output cards (cards one to seven). The processing unit card is located in slot 0, and input cards that made up of digital and analogue cards; the digital switches, optional contacts, and push buttons are located in slots 1 and 2, with solar sensors, and batteries bank. The voltage sensor is located in slot 3 channels 1 and 2 respectively, and the output card is located in slot 4, the 4-20 mA in the series method is used, and the 4-20 mA inputs are connected in series with the programmable logic controller. For example, a reading of 4 mA (lowest value) corresponds to 3277, and 20 mA (highest value) corresponds to 16385. There are thirteen discrete inputs to slot one (24 VDC) with spare spares. Slot two has seven discrete inputs (24 VDC) with spare spares. The correlation of both analogue and discrete inputs according to the notation preference will define the correct selection of output solar contactor and batteries bank voltage sensor, as renewable solar cells and batteries bank cells started both via the processor's slot 4 to activate the coils R2 and R3 respectively, solar and batteries bank cells.

Power supply for SLC 500	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7
	Process or	Input	Input	Analog. Input	Output	Spare	Spare	Spare

Fig. 6: PLC's Controller Boards Layout

Fig. 7 shows hybrid Solar - batteries bank cells and diesel systems. Solar - batteries bank cells connected in parallel, connected to the DC bus bar, and then converted to AC voltage via the inverter after a word is supplied to the AC bus bar and then will supply the electrical power to the load.

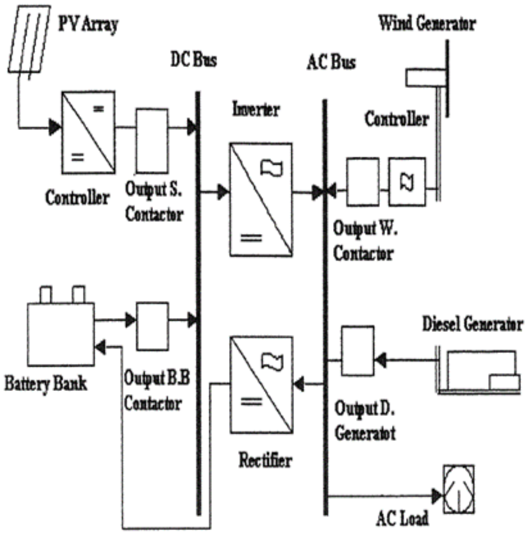

Fig. 7: Hybrid system of solar and batteries bank cells - diesel generators.

Fig.8 shows the management proposition for the Hybrid System for solar _ batteries bank – diesel generators, which consists of AB SLC 500 as a controller. By forwarding the discrete inputs to slots 1 and 2 (first–opening addressing), The processing unit assigns the first opening as one discrete group, each opening is sequentially assigned one word (sixteen bits) of an SLC module's input and output image. Each store on the I/O module allocated a bit within the word, starting with the least significant bit. Input-opening addressing is essentially prepared to stand by input/output modules whose image size is less than or equal to one word but more than one byte. 13 digital inputs are connecting to 13 terminals in slot 1, and 6 digital inputs are connecting to six terminals in slot 2. These digital inputs are starting or stopping the push button or normally closing or normally opening additional contacts or normally opening switch.

Slot 3 is the analogue input module. Each input of the input card is assigned sixteen bits in the image table as an input. Each input of the input card employs sixty-four bits in the image table as inputs; the converted values from channels one to three address input words one through three individually for the opening where the card stays. Channel 3 is a spare. Slot 4 is the discrete output. Discrete outputs are connected to terminals one and two respectively belonging to solar and batteries cells in slot four, while terminal 3 is connected to the output diesel contactor. Each depot allocates a bit first with the lower important bit. The management proposition for Hybrid System for solar _ batteries bank – diesel generator has been performed by the combination of these analogue and discrete inputs, and discrete output (slot 3, 1, 2, and 4).

The software has been built in slot 0 (the processor) from this combination to run the management proposition for Hybrid System. For the solar batteries bank – the diesel generator system is achieved as following idea; if the solar light and heat are strong enough (more than 10 V and less than 16V) then the output solar contactor will be activated, and due to this, it will connect the solar contactor at the output rod for direct current. Batteries cells' voltage sensor is strong enough (more than 10 V and less than 14 V) then the batteries cells' voltage sensor will be activated, as a result, it will connect the batteries cells' voltage contactor to the output DC bus bar as well, the solar cells and batteries cell are connected in parallel. The management proposition for Hybrid System for solar _ batteries bank – diesel generators prefer to be used in a remote area.

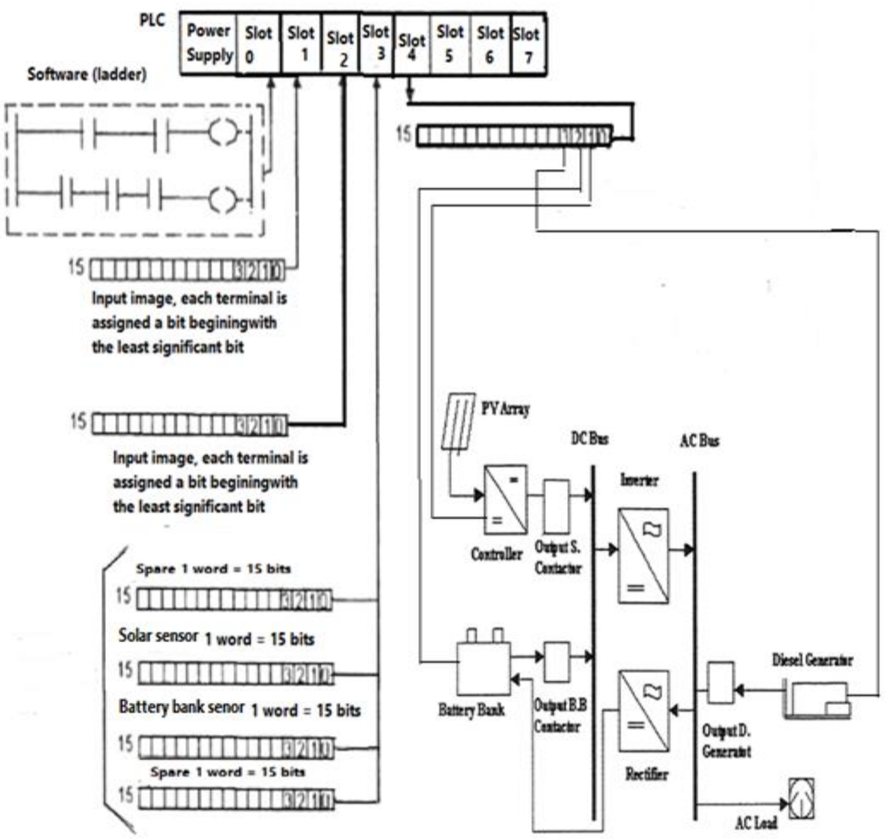

Fig.8: Control plan of solar and batteries bank cells - diesel generators.

A longitudinal relation of this method is utilized to calculate the rate, and offset, and can be performed as shown for solar cells. It shows two coordinates, the horizontal coordinate shows the input values (current in mA) while the vertical coordinate shows the scaled range in voltage v as shown in Figure 9, the formulas linear relationship between these two values is expressing the formulas below:

$$Slope = \frac{Scaled\ Range}{Input\ Range} \quad \ldots (1)$$

$$Offset = \min\ \_scale - (min\_input\ value * Slope) \quad (2)$$

$$Rate = Slope * 10000 \ldots (3)$$

The values Slope, Offset, and Rate for solar cells 10 to 16 V are:

Slope = 6 / 13107 = 0.0005

Offset = 10 – (3277 X (6/13107) = 28.36 = 28

Rate = 0.0005 X 10000 = 5

$$Rate = Slope * 10000$$

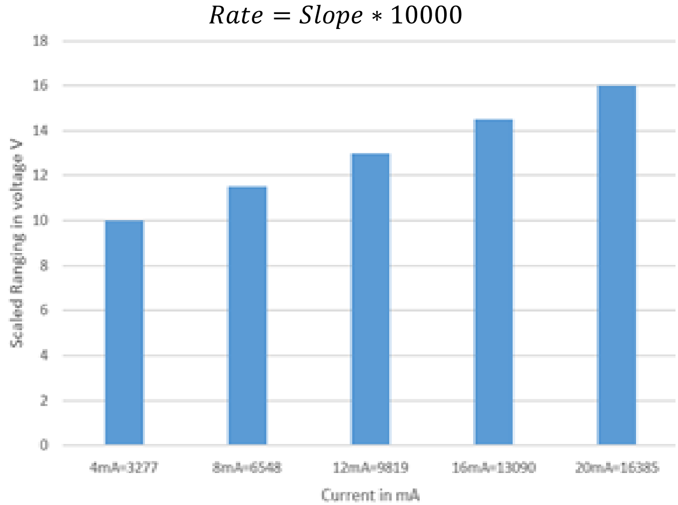

Fig.9: Scaling graph of solar voltages

The scaling values for batteries bank voltage sensor are shown in Fig. 10 and shown as below:

$$Slope = \frac{Scaled\ Range}{Input\ Range} \quad \ldots (4)$$

$$Offset = \min\ \_scale - (min\_input\ value * Slope) \ldots (5)$$

$$Rate = Slope * 10000 \ldots (6)$$

The values Slope, Offset, and Rate for batteries bank is 10 to 14 V are:

Slope = 4 / 13107 = 0.0003

Offset = 10 – (3277 X (4/13107) = 10 – 1.00007 = 9

Rate = 0.0003 X 10000 = 3

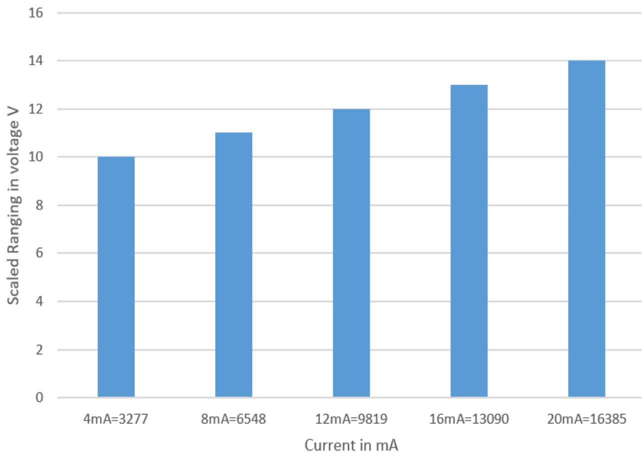

Fig.10: Scaling graph of batteries bank.

III. CONCLUSIONS

According to the above tests, we found the voltage produced by solar cells varies between 10 - 16 V, while the voltage produced by batteries bank is 10 to 14 V. connecting 15 panels of solar cells in series. Connecting 17 batteries bank in series. Both over whole sets of solar cells and batteries bank connected in parallel. The resultant voltage feeds the inverter and is controlled by PLC. Found that the voltage, which is produced by this combination, is producing voltage varies between 220 V – to 240 V for six hours starting from 10 AM till 4 PM. This controlling path is using PLC, which is controlling the hybrid system of green energy-diesel generators performed by the SCADA system. Future work is needed for implementing this research of hybrid solar and batteries bank-diesel generators in a rural area is highly recommended to increase the friendly green environmental generators, and it should continue to achieve the optimum method for controlling the multiple renewable energy sources.

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